EECS 142 Laboratory #1

Calibrating Network Analyzers
&
Tools and Tips for RF Electronics

August 30, 2018

1 Introduction

At high frequencies, we use network analyzers to make S-parameter (scattering parameter) measurements. Instead of impedance measurements where a port would need to be either open or shorted (hard to achieve at high frequency), an S-parameter measurement uses a 50 ohm load at each port. Network analyzers can save these measurements in a S-parameter ("Touchstone") format which RF CAD tools can read. In later labs, you'll convert the S-parameters format to Y or Z parameters to build circuit models. You'll need to model device parasitics later so that you can account for them in the following labs. At high frequencies, if you don't account for these parasitics, then your circuits won't perform as designed.

When you find things aren't working as expected, you'll want to use a general debugging strategy of "going back to something that works". This lab is designed to give you a few of those atomic units of "something basic that works right" that you can go back to. (Is my circuit design flawed, or is my cable bad? Is my network analyzer broken or did I push the wrong buttons?) In this lab, you'll *test your test equipment* to make sure that you have a foundation for successful measurements.

1.1 Expectations

1.1.1 Groups

You should work in groups of ideally two, but up to three, members. Groups may turn in a single pre-lab and lab report.

1.1.2 Pre-Lab

Complete and submit your pre-lab before attending your lab section. Unless otherwise specified, pre-labs will be graded primarily on completion and will not require a formal write-up; it is enough to show your calculations and results. Some lab report questions may ask you to refer to your pre-lab calculations or results; for those questions, consider incorporating relevant parts of your pre-lab in your lab report.

1.1.3 Lab Reports

Your lab will be evaluated primarily on the basis of the lab report you submit. Your evaluation may include the following criteria, in no particular order:

- Answers to lab questions
- Clear measurements (and calculations if necessary) of specified performance metrics of the devices you build
- Comparisons of predicted, simulated (if applicable), and measured results. If there is a discrepancy, commentary on why.
- Raw measurements, in a standard file format, where required. Please keep the final devices you build; you may be asked to reproduce your results.

- Neatness, readability, and organization of text, figures, and other supporting material

Some classes ask for lab reports that stand on their own (e.g. with a purpose, procedure, conclusions, etc.). You may choose to write your lab reports however you wish; we're fine if you just answer the questions.

1.1.4 Feedback and Regrades

If you need additional feedback on your lab grades, please ask. Regrade requests will be honored for grading errors or inconsistencies and are due a week after lab grades are available.

2 Pre-Lab

1. Read the Lab Manual and complete the Qualified User Quiz.
2. Familiarize yourself with your CAD tools, if you haven't already. We will primarily use S-parameter simulations, S-parameter conversions, filter designers, and occasionally optimizations. No submission is required for this part.
3. A narrow (with respect to the delay of the transmission line) voltage pulse is launched through a matched termination from one end of a 50-ohm transmission line. Sketch the voltage vs. time of at the same end of the transmission line when the other end is terminated with:
   (a) A short
   (b) 25 ohms
   (c) 50 ohms
   (d) 100 ohms
   (e) An open

   Indicate the relative heights of the pulses.
4. Describe or sketch, qualitatively, the one-port S-parameters (magnitude/phase or Smith chart) of an open, short, and matched load. (This means that the reference plane is *at* the open, short, or matched load. While you will always make these measurements through a length of transmission line, your reference plane defines a point where there is zero loss and no phase shift.)
5. How do your above answers change if there is a length of transmission line between the reference plane and the open, short, and matched load?
6. Finally, you should always consider skimming the entire lab before you attend your lab section so that you can get questions answered in advance and spend less time in lab.

3 Experimental Work

3.1 Connectors, Cables & Calibration

1. Inspect two cables. Call over a GSI and demonstrate connecting the cables to the VNA.

2. Pre-test the two cables. Save screenshots of the Data − Mem display after pre-testing both cables. Take a picture of the two unconnected ends of the cable showing the pin and dielectric (`ends.jpg`).

3. Before performing a calibration, measure and save the one-port S-parameters of the open standard (`precal-open.s1p`).

4. Perform a one-port manual calibration.

5. Measure and save the one-port S-parameters of the open (`manual-open.s1p`) or short (`manual-short.s1p`) standards from the same manual calibration kit.

6. Perform a two-port electronic calibration.

7. Measure and save the one-port S-parameters of the open (`ecal-open.s1p`) or short (`ecal-short.s1p`) standards from any manual calibration kit.

8. Measure and save the two-port S-parameters of a female–female through adapter (`ff-thru.s2p`).

3.2 Soldering

You will solder 4 boards: an Open board, a ShuntShort board, a Thru board and a ShuntDUT board. Save these boards for Lab 2. Make sure the backside of each board gets soldered appropriately (as pictured in the ppt and as illustrated in Chapter 9 of Dunsmore's book). Use flux whenever you solder, and inspect the board under the stereo microscope.

1. Solder end launches to your boards.

2. Measure and save the two-port S-parameters of your "Thru" (`pcb-thru.s2p`), "Open" (`pcb-open.s2p`), and "ShuntShort" (`pcb-shuntshort.s2p`) boards.

3. Practice soldering and desoldering a surface-mount component to and from the "Open" board. Inspect your joints under a microscope.

4. Clean up. In future labs, you may consider leaving your cables attached to the VNA. However, for this lab, you should disconnect and return your cables.

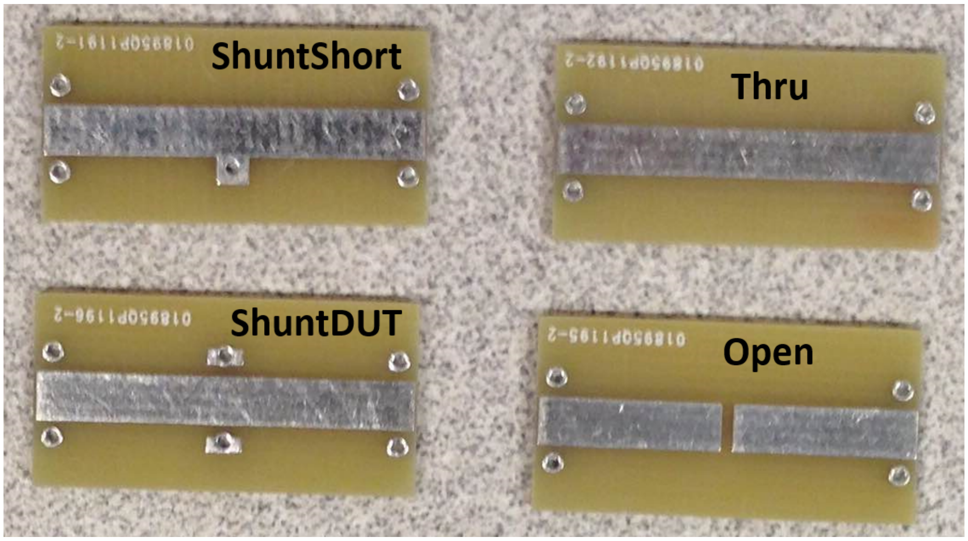

Figure 1: PCBs that will be used in this lab.

4 Lab Report

1. Plot the S-parameters (vs frequency) of the short or open you measured using the manual calibration. Does it match what you predicted in the pre-lab? If not, what would explain the discrepancy?

2. Repeat Part 1) with the standard you measured using the electronic calibration.

3. Plot the S-parameters of the female–female through adapter. How much loss is there? Is it well-matched to 50 ohms? Why or why not?

4. Repeat Part 3) with the "Thru" board.

5. *(bonus)* Using your favorite CAD tool's optimization function, find a characteristic impedance and loss coefficient that better models your "Thru" board. Overlay the S-parameters of your model with those from your measurement.

6. Plot just the S11 or S22 of the "Open" board. How does it compare with an ideal open? Why?

7. Submit your lab report, along with the measurements and images you took in lab, as a ZIP archive.

5 References

Joel Dunsmore's book, *Handbook of Microwave Component Measurements* is the final word on network analyzer measurements. We have a copy in the lab and it's also available online at the UCB library site.