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ECEN 5634
Lab 2 Report

Part I

It is much easier to damage low input impedance instruments, because by Ohm's Law, even a small voltage can lead to a large current which may be enough to damage the VNA. This is why it is important to wear the ESD strap and avoid touching the inner conductors.

Q1: The network analyzer performs the measurement at frequency intervals of $\frac{3\ GHz - 300\ kHz}{200} = \frac{2.9997\ GHz}{200} = 14.9985\ MHz \approx 15\ MHz$. Using the default settings, the VNA takes 1 measurement at each frequency (no averaging).

Q2: After we performed our calibration, the reference plane was located at the SMA connector at the end of the cable.

Q3: After the calibration, we should expect the open circuit standard to have a reflection coefficient on the very right point of the Smith chart, which means that its phase will be 0° and its magnitude will be 1 (which is 0 dB). We expect the short circuit standard to have a reflection coefficient on the very left of the Smith chart, which means that its magnitude will also be 1, but its phase will be 180°. We expect the load calibration standard to be in the center of the Smith chart, which means that its reflection coefficient will be 0.

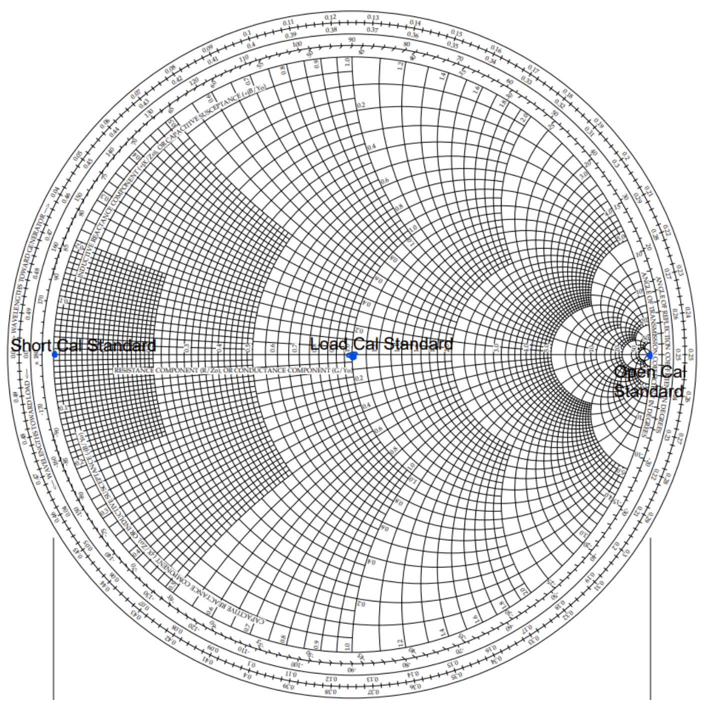

Figure 1: Expected reflection coefficients of calibration standards on the Smith chart.

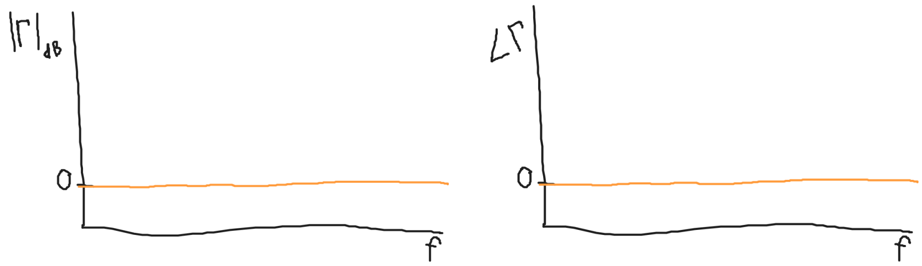

Figure 2: Expected magnitude (left) and phase (right) of open circuit standard after calibration.

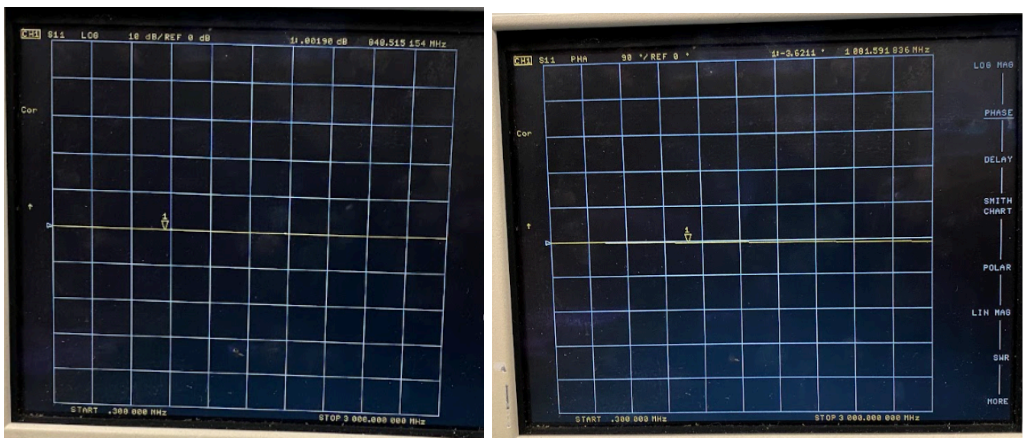

Figure 3: VNA S_{11} magnitude (left) and phase (right) plots of open circuit standard.

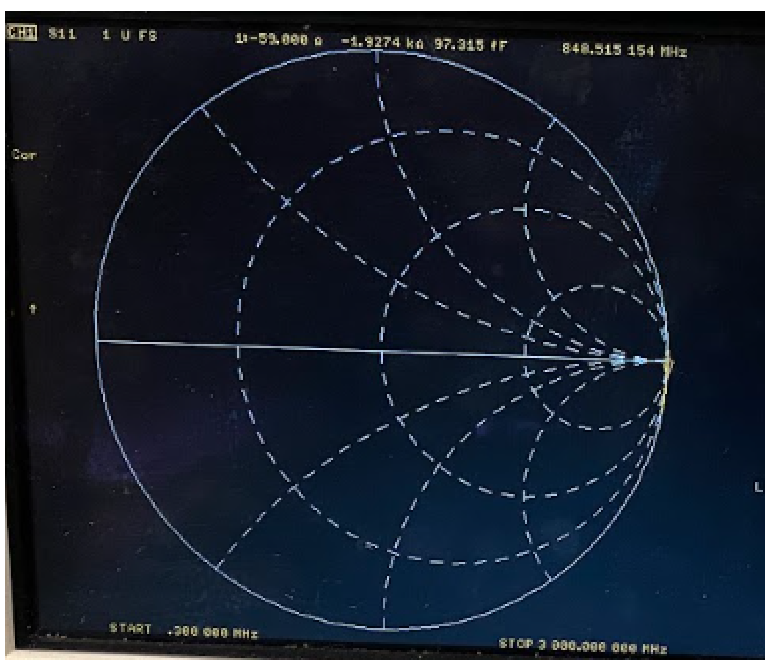

Figure 4: VNA Smith chart of open circuit standard

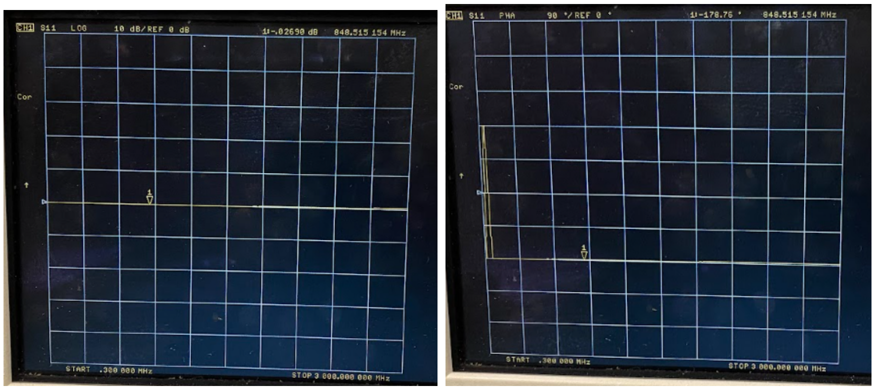

Figure 5: VNA S_{11} magnitude (left) and phase (right) plots of short circuit standard.

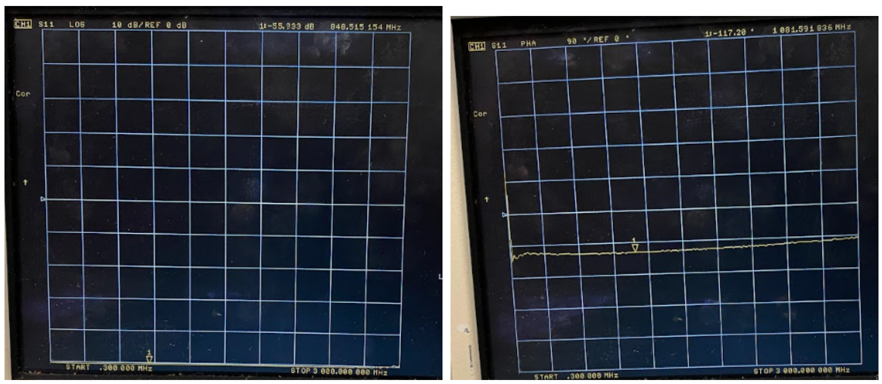

Figure 6: VNA S_{11} magnitude (left) and phase (right) plots of load calibration standard.

As we expected, the magnitudes for the open and short circuit calibration standards were both approximately 0 dB, and the magnitude for the load calibration standard was approximately 0 (we measured -55 dB). These plots are correct because they show that after calibration, each standard is where we theoretically expect it to be. In addition to the magnitudes matching our expectations, the phases do as well. The phase for the open circuit is close to 0°, the phase for the short circuit is 180° (which is the same as -180°), and the phase for the load is irrelevant, since its reflection coefficient lies in the center of the Smith chart. (We did measure a fairly consistent phase of -117°, which tells us that our reflection coefficient had a slight offset from the center, but our measured magnitude was small enough to say that this was insignificant.)

Part II

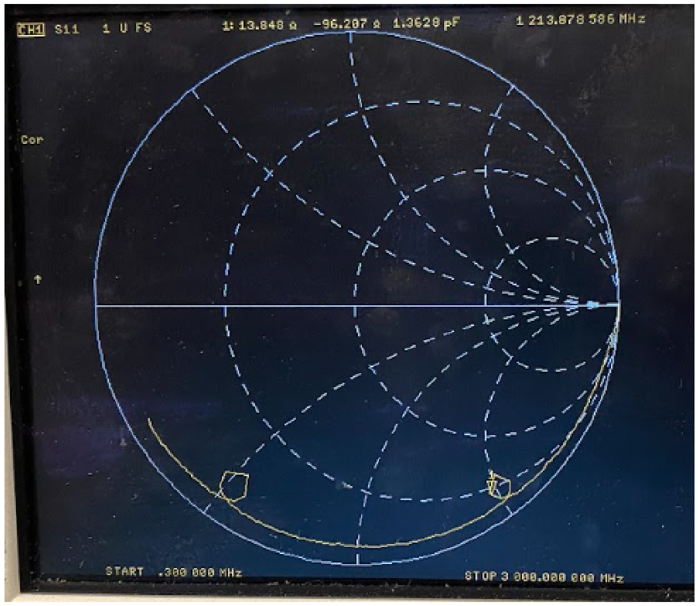

Figure 7: Smith chart of microstrip open circuit.

Q4: The microstrip open circuit Smith chart looks different from the coax open calibration standard Smith chart because they are different circuits, and the VNA has been calibrated with the coax. When performing the calibration, the VNA took into account the known capacitance of the calibration standard. The microstrip circuit has added length and different parasitics than the calibration standard, which have not been adjusted for by the calibration, so we see its capacitive element in the Smith chart.

Part III

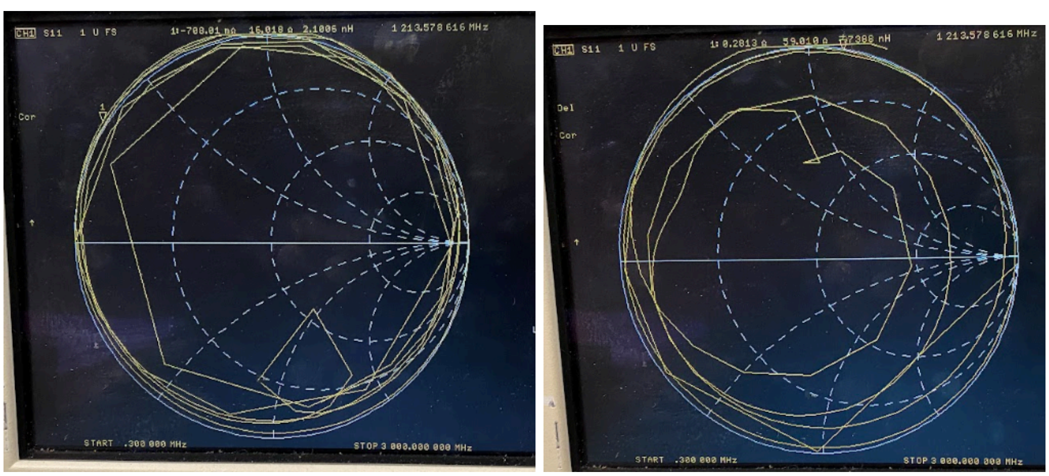

Figure 8: GR inductor (left) and capacitor (right) Smith charts using initial calibration.

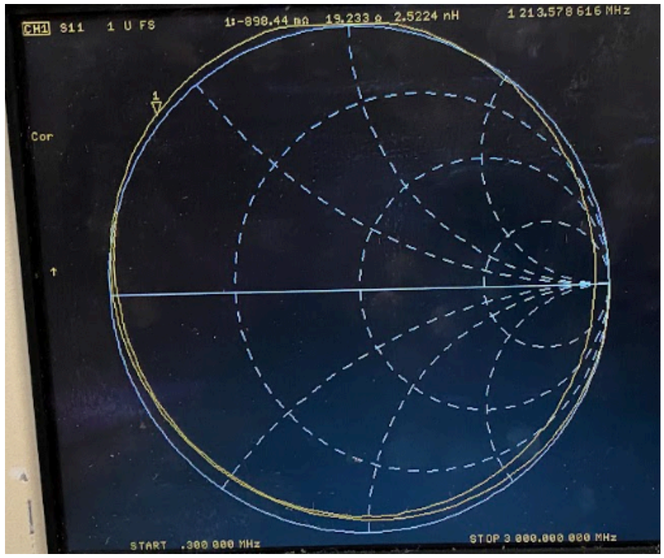

Figure 9: Empty GR component mount Smith chart using initial calibration.

Q5: The accuracy of the GR inductor and capacitor measurements is greatly affected by the adaptor, the component mount, and the cover shield. All of these pieces introduce parasitic effects that make our measurements different from what we would expect with only a capacitor or only an inductor. We found that all three of the Smith charts in this part using the initial calibration (inductor in component mount, capacitor in component mount, and empty component mount) looked very similar.

Q6: After performing the SOLT calibration with the SMA-to-GR874 adapter attached to the cables, as well as a 90° bend on the end of port 2, the reference plane is located at the end of these components. On port 1, it is at the end of the adapter, and on port 2, it is at the end of the 90° bend.

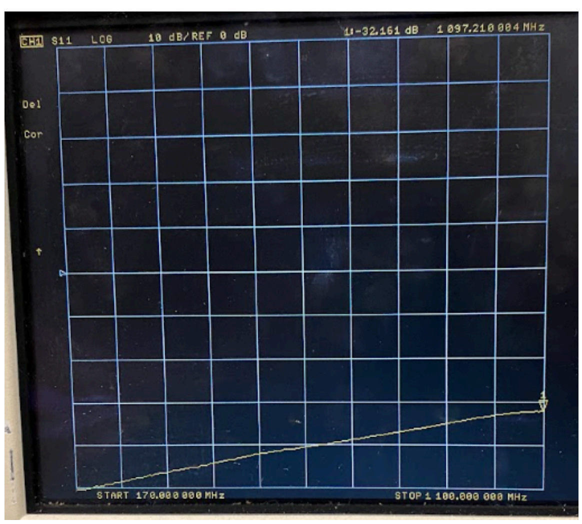

Figure 10: 50 Ω load S_{11} magnitude after new calibration. The maximum magnitude is -32 dB.

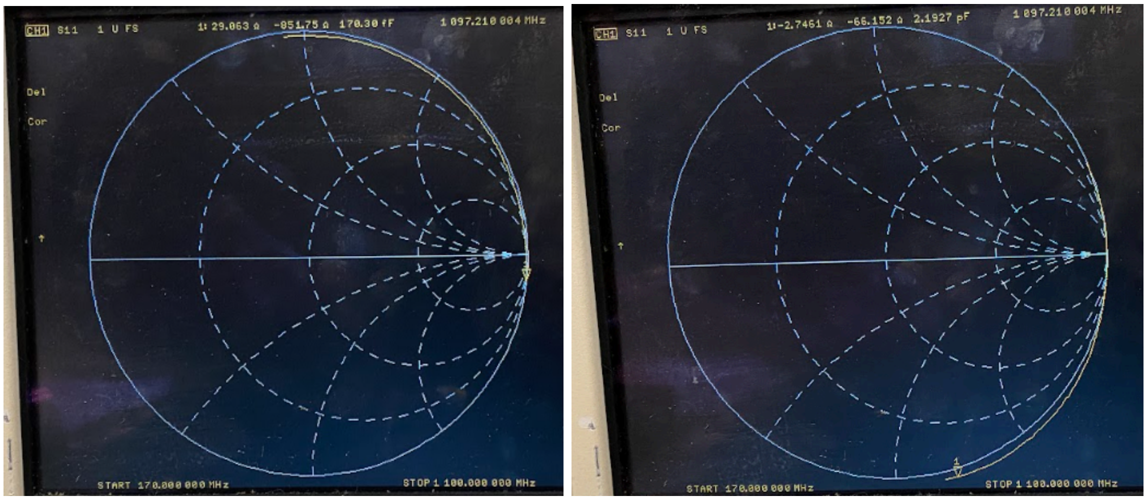

Figure 11: GR inductor (left) and capacitor (right) Smith charts using new calibration.

Q8: We saw significant changes in our measurements of S_{11} for the GR components after the new calibration. After the new calibration, each Smith chart is more of what we would expect of an inductor and a capacitor. They no longer wrap around the Smith chart multiple times, but rather just show a change in reactance with frequency (the capacitive reactance decreases in magnitude as frequency increases, while it is the opposite for the inductor). They also now stay on the outer edge of the Smith chart (representing 0 resistance) and do not have any resonance.

Part IV

For this part, we first performed a new calibration for the new frequency range, which is required because the VNA is taking measurements at different frequency points than it was before.

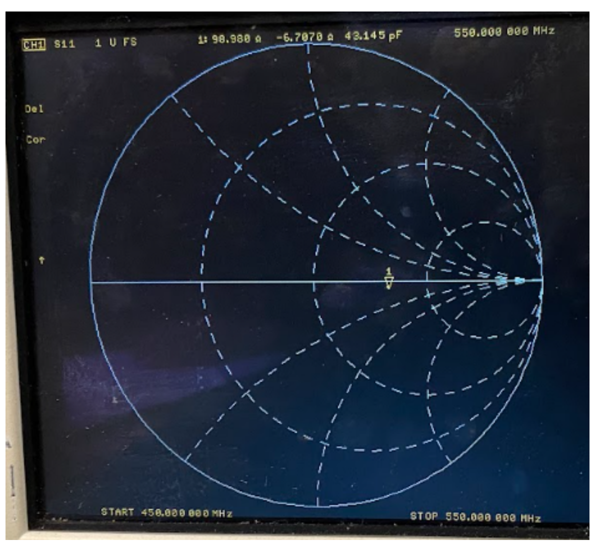

Figure 12: Smith chart display of S_{11} with 100 Ω load.

Q10: The value of the impedance read off the display is (98.98 - j6.71) Ω, which is slightly less resistance than the 100 Ω impedance we expected, and has a capacitance that we did not expect. We did not measure the DC value with an ohmmeter, but assumed that it was 100 Ω. We would expect the resistance to increase with frequency due to the skin effect, so we think that the reason for the discrepancy is that the 100 Ω load is not perfectly 100 Ω and that there are uncompensated parasitic effects, because it was the 50 Ω load that was used in the calibration. The measured SWR was 1.98.

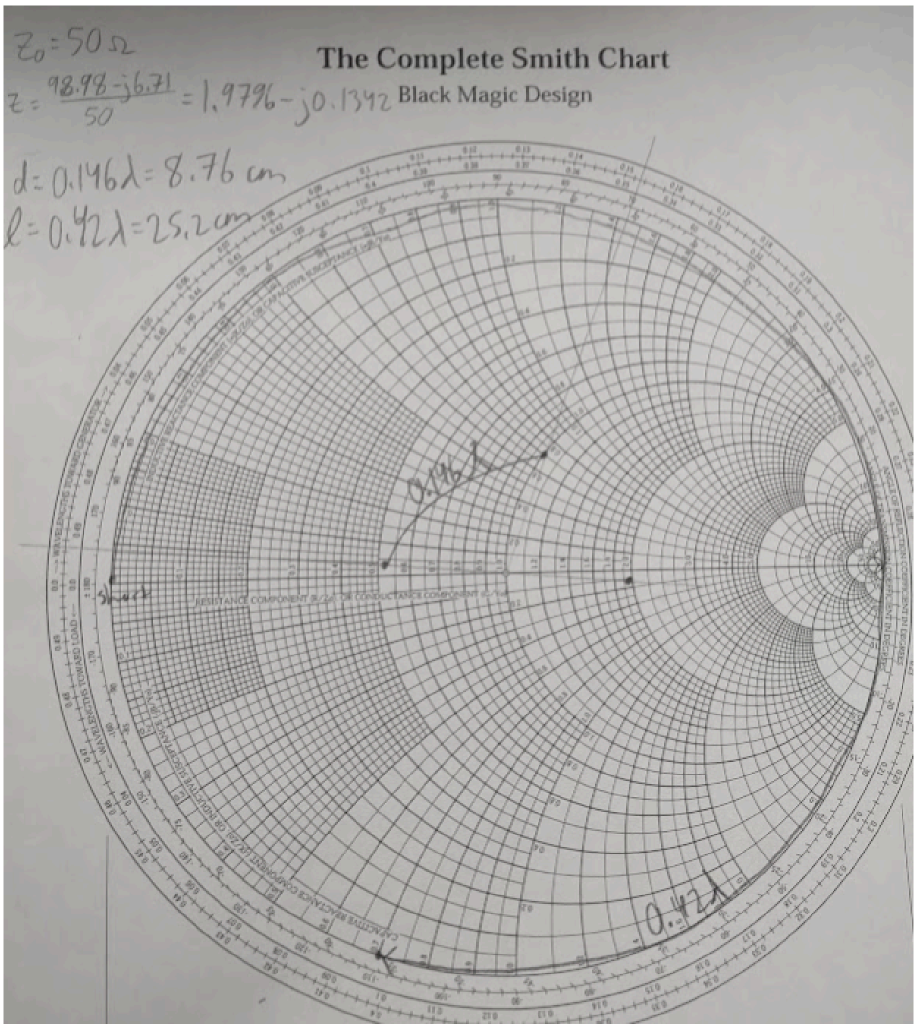

Figure 13: Theoretical stub match for (98.98 - j6.71) Ω load using Smith chart. We found d=8.76 cm and l=25.2 cm

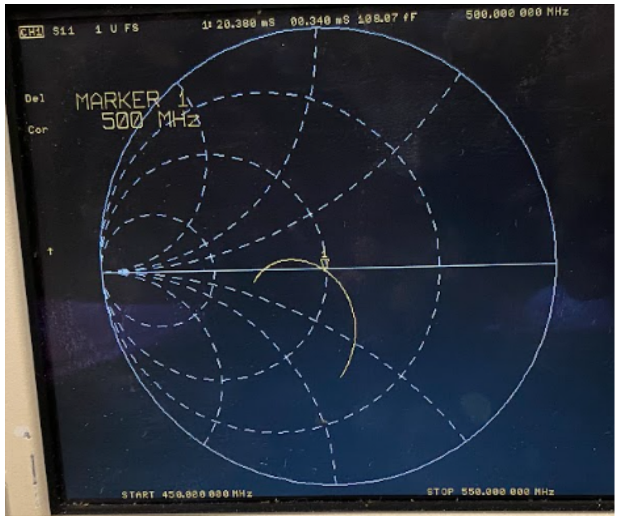

Figure 14: S_{11} Smith chart after adjusting stub length and location to match load. Our measurements showed that we achieved this with *d*=46 cm and *l*=21 cm.

Part V

Q11: We expect to measure SWR of 1, because the stub is acting as an open circuit (a quarter-wavelength away from a short is an open) so it is as though the stub is not there at all, since it is infinite resistance in parallel with the line terminated with the load. Since we are using the 50 **Ω** load, we expect it to be matched, which implies a reflection coefficient of 0, and SWR of 1. With the quarter-wavelength stub, we got SWR very close to 1, but not quite a perfect match, which is likely due to the parasitic effects in the T-junction. After adjusting the stub to get to the center of the Smith chart, we found that the match was achieved with the stub having length 15.4 cm, slightly above the quarter-wavelength of 15 cm.

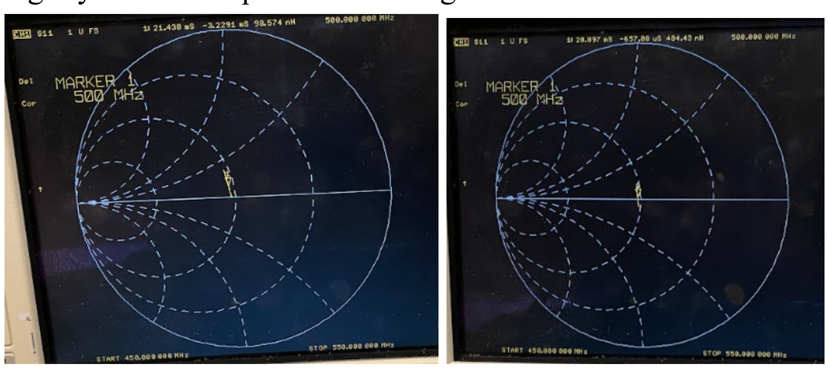

Figure 15: S_{11} with 50 **Ω** load and stub of length 15 cm (left) and length 15.4 cm (right)

Our final experiment was to use the same method to match the GR capacitor using the short stub. We found that we were unable to do so until we removed the adjustable stub, added extra length of coax line (the through component), and then reattached the adjustable stub. We achieved the match with *d*=45 cm and the adjustable stub length set to 18.1 cm