EE 117B/217B Microwave and Wireless Measurements

Lab 2 Questionnaire - Time Domain Measurements Using VNAs

Fall 2026

Group members: ____________________

Answer each question in the space provided. Questions marked [**EE 217B only**] are required for 217B students and optional for 117B students. One combined report per lab group.

1. Introduction to Time Domain and Time Gating

1.1 Time Domain Experiments

Q1.1.1: Comparing the live data with the stored memory trace for the 1 m cable on Port 1: how many peaks do you see in each trace, and what is the origin of each one?

Q1.1.2: With the 10 dB attenuator on the end of the extension cable, explain the origin of the different peaks, including the change in each of their magnitudes.

Q1.1.3: With the long delay line connected, explain the origin of the two large peaks. Do you also see the reflection from the far end of the delay line?

Q1.1.4: With `Stop Time` at 100 ns, estimate roughly the one-way loss in the delay line.

Q1.1.5: From the positions of the major peak and the peak at the start of the delay line, determine the approximate physical length of the delay line, assuming $\varepsilon_r = 2$ (Teflon).

Q1.1.6: Explain the origin of the two smaller peaks at negative time.

Q1.1.7: Sweeping the number of points from 101 up to 10001, at what point do you start seeing the "correct" time-domain response — that is, the point beyond which it no longer changes?

Q1.1.8: Did the peaks at negative time disappear? Comment on the relationship between the two small peaks near 200 ns and the peaks you saw earlier at negative time.

Q1.1.9: With the 1 m SMA $\rightarrow$ HPF $\rightarrow$ 1 m SMA $\rightarrow$ 10 dB pad chain over 1–2 GHz, explain the features of the observed response. How many large distinct peaks do you see?

Q1.1.10: With the stop frequency raised to 5.0 GHz, how many large distinct peaks do you see and what is the origin of each? Include the saved trace as a plot with your answer.

Q1.1.11: [**EE 217B only**] Measure the 6 dB width of the peak at 0 ns. Compare it with the theoretical value from the 1–5 GHz bandwidth and estimate the Beta-factor of the Kaiser–Bessel window. Then find the Beta-factor in the VNA settings and check it against your result.

Q1.1.12: [**EE 217B only**] For the same ≈4 GHz bandwidth, why is the temporal resolution different between the band-pass (1–5 GHz) and low-pass (30 kHz–4 GHz) cases?

1.2 Time Gating

Q1.2.1: With the 1 m cable between the ports, S_{21} gated to a 1.5 ns span, and the gate centre nudged off the peak, the band edges rise above 0 dB — the wire appears to have gain. Explain why gating can push the response above 0 dB, and why this is not a violation of passivity.

Q1.2.2: Plot the frequency-domain response of the 10 dB pad with `Gating ON` and with `Gating OFF`.

Q1.2.3: With gating off, the response exceeds −20 dB at several frequencies even though there is at least 20 dB of attenuation in the signal path. How is that possible?

Q1.2.4: Calculate the time separation between the two time-domain peaks from the ripple period measured in the frequency domain, and compare it with the peak spacing measured directly in the time domain.

Q1.2.5: [**EE 217B only**] Using the S1P data you collected, use AI to implement your own time-domain transform and time gating. Plot the gated time-domain and frequency-domain responses of the 10 dB pad and compare them with the gating applied internally by the FieldFox.

2. TRL Calibration and De-Embedding

2.1 Step 1: Setup and First-Tier Calibration

Q2.1.1: For the 17 mm line, up to what stop frequency is the TRL calibration valid, taking $\beta\Delta\ell = 160^\circ$ as the upper limit? Give the expression you used, state the ε_{eff} you assumed and where that value came from, and report the f_{stop} you set on the instrument. After you have solved the calibration (Q2.3.1), come back and recompute this limit from the ε_{eff} you actually measured — does your chosen f_{stop} still sit inside the valid range?

Q2.1.2: Do you really need the first-tier SOLT calibration at the ends of the extension cables? Explain why or why not.

Q2.1.3: With the two cables connected through the coaxial THRU, report the magnitude of S_{21} after `Autoscale`.

2.2 Step 2: Connect the TRL Standards

Q2.2.1: Looking at S_{21} and S_{11}/S_{22} of the board THRU, does it look like an ideal THRU? If not, why not?

Q2.2.2: Is the REFLECT structure a short or an open? Explain how you determined this from the Smith chart.

2.3 Step 3: Solve for the Error Terms

Q2.3.1: Plot the extracted attenuation constant α and phase constant β versus frequency, and report the effective permittivity ε_{eff} of the substrate.

Q2.3.2: Plot the recovered reflect coefficient Γ_R on a Smith chart. Does it match the physical standard on the board?

Q2.3.3: Plot the magnitude of all seven independent error terms versus frequency: e_{00}, e_{11}, $e_{01}e_{10}$, e_{33}, e_{22}, $e_{23}e_{32}$, and $e_{10}e_{32}$.

2.4 Step 4: Verification

Q2.4.1: Overlay $|S_{11}|$, $|S_{21}|$ and $|S_{22}|$ of the raw and de-embedded `File_T_2.s2p`. Plot the residual error and report the worst-case deviation in dB.

Q2.4.2: Measure the THRU in the time domain and gate out the launch reflections instead. Which method removes the launch more cleanly, and why?

3. Extraction of Passive Elements

Q3.1.1: Model each DUT as an unknown length of transmission line, the lumped element, and a second unknown length of line. Using the four devices whose values you know (1 nH, 10 nH, 1 pF, 100 fF), extract the left and right line lengths, then use those lengths to extract the unknown inductor (device 3) and the unknown capacitor (device 6). State the model and the equations you inverted, and report all extracted quantities.

Q3.1.2: What is the error in the extracted values for the four *known* components? Which device shows the largest error, and why?

Q3.1.3: What is the self-resonance frequency of each of the three inductors and each of the three capacitors? Which device resonates lowest, and why? State which of these fall inside your calibrated band.

Q3.1.4: Device 7 is a series inductor followed by a shunt capacitor — the lumped model of a bondwire landing on a pad. Can you find a way to extract L and C independently from a single measurement? Give the method and both values, and compare them with the isolated devices 1 and 4.

Q3.1.5: [EE 217B only] Measure the spacing between the two capacitors of device 8. What VNA bandwidth (stop frequency) is required to resolve them as separate features in the time domain? Show the calculation.

Q3.1.6: [EE 217B only] Gate each capacitor of device 8 separately and report the apparent $|\hat{\Gamma}_1|$ and $|\hat{\Gamma}_2|$. Apply the masking correction $|\Gamma_2| = |\hat{\Gamma}_2|/(1-|\hat{\Gamma}_1|^2)$ and compare the corrected $|\Gamma_2|$ with the time-gated Γ of the single 1 pF capacitor (device 4).

4. Time Domain Reflectometry

Q4.1.1: With the transform in `Low Pass Step` and the format set to `Imaginary`, the trace should be zero to within the noise. Explain why low-pass mode forces this and band-pass mode does not.

Q4.1.2: Where in the time record does the board appear? Confirm the position against the length of your extension cables.

Q4.1.3: From the step response of the THRU, what lumped-element model would you use for the SMA connectors? Justify your answer from the shape of the trace, and explain why the far-end launch looks different from the near-end one.

Q4.1.4: From the step response of the REFLECT standard, is it a short or an open? How can you tell immediately here, when it took a Smith chart in the frequency domain?

Q4.1.5: Using the area rule derived in the manual's appendix on the area method, estimate the value of each of the six passive elements from the area under its step response. Tabulate them alongside your frequency-domain values from Part 3 and comment on any disagreement.

Q4.1.6: Does the step response of device 7 agree with what you expect for a series inductor followed by a shunt capacitor? What does its shape tell you about the SMA launch you looked at in Q4.1.3?

Q4.1.7: Gate each of the two series capacitors of device 8 separately and plot the step response of each. Do they look the same? If not, why not?