EE–576 Electromagnetic Compatibility
Laboratory 1: Network Analysis

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Leave blank. Group ID: ______________________________

Names of the group participants (up to three students):

Name and SCIPER: ______________________________

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The questions marked *(Lab)* should be done in priority during the lab session. The remaining ones can be completed at home later.

Please hand in this document with your answers by **March 27, 2025**.

1 Introduction

In this laboratory session, you will get hands-on experience with a vector network analyser (VNA) and scattering parameter measurements. This session builds upon the lecture on network analysis given last week.

Objective:

1. Become familiar with a portable network analyser (VNA),
2. Understand a calibration method and its effect,
3. Perform basic scattering parameter measurements and analysis on coaxial cables, and
4. Use time-domain measurements.

2 Practical session

Before you begin, complete the following checklist to make sure you have all the necessary equipment:

- ☐ LiteVNA
- ☐ User interface reference sheet
- ☐ Strap
- ☐ 2 blue SMA RF cables
- ☐ 2 silver SMA RF cables
- ☐ 2 SMA through adapters
- ☐ Calibration kit (see fig. 1):
  - ☐ Through
  - ☐ Load
  - ☐ Short
  - ☐ Open
- ☐ USB cable
- ☐ USB power brick

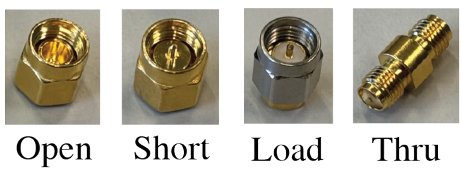

Figure 1: Contents of the calibration kit.

Take a moment to learn how to navigate in the VNA menus. You can try to use a pen to use the touchscreen. There is also a knob that you can use to scroll and select. The user interface reference sheet can help you find parameters.

2.1 Calibration

1. (No measurement needed here.) Complete fig. 2 with a plot of the expected $|S_{11}|$ and $|S_{21}|$ for an ideal VNA where both ports are left open. Plot both curves on the same plot; there are two y-axes. Please clearly label each curve.

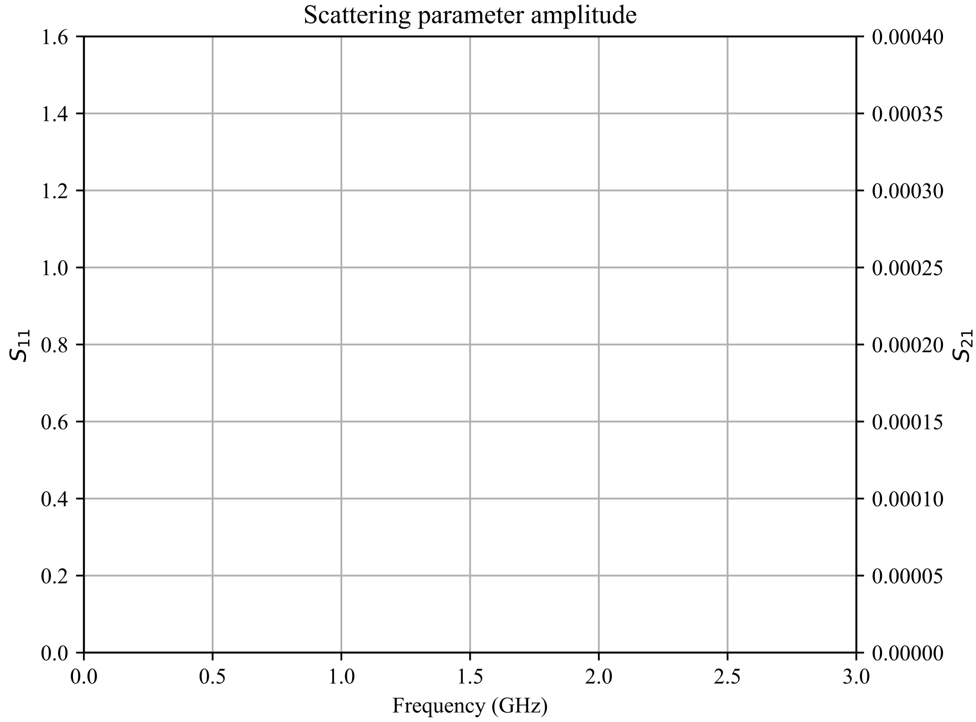

Figure 2: Expected scattering parameters (to be completed).

2. *(Lab)* Connect both silver cables to the VNA. See fig. 3 for the corresponding setup.

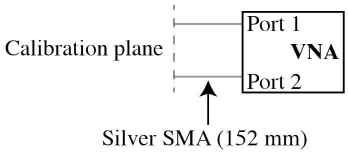

Figure 3: Calibration setup.

3. *(Lab)* Set up the VNA:
   1. Start by a reset (`Calibrate > Reset all`).
   2. Ensure Marker 1 is enabled (`Marker > Select marker`). Make sure tracking is disabled (`Marker > Tracking`).
   3. In Display, activate only traces 0 and 1. Go to `Display > Trace`. A trace is active when it is shown in color in the menu. A checkmark indicates that it is selected for other actions (e.g., format selection). Repeatedly press the same trace to toggle between active/selected/disabled.
   4. Disable averaging (`Display > AVG > None`).
   5. Set trace 0 to display S_{11} (`Display > Trace` to make sure it is active and selected, then `Display > Channel` until it shows `S11 (REFL)` in linear format (`Display > Format (S11 REFL) > More > Linear`), scale 200 m/div (`Display > Scale > Scale/div > 0.2`), reference 0 (`Display > Scale > Reference position > 0`).
   6. Set trace 1 to display S_{21} in linear format, scale 50 µ/div, reference 0.
   7. Set the stimulus from 30 kHz to 3 GHz (`Stimulus > Start` and `Stimulus > Stop`) and 401 points (`Stimulus > CFG sweep > Sweep points`).

8. Save this setup in the first slot (`Calibrate > Save > first slot`).

4. *(Lab)* The top of your screen always shows all trace information (measurement, format, scale). The active marker frequency and corresponding amplitudes are also indicated. On the bottom of the screen, the frequency start, stop, and number of points are indicated.

5. Why are only S_{11} and S_{21} (and not S_{12} and S_{22}) available in this VNA?

6. *(Lab)* Sketch the measured data ($|S_{11}|$ and $|S_{21}|$) in fig. 4.

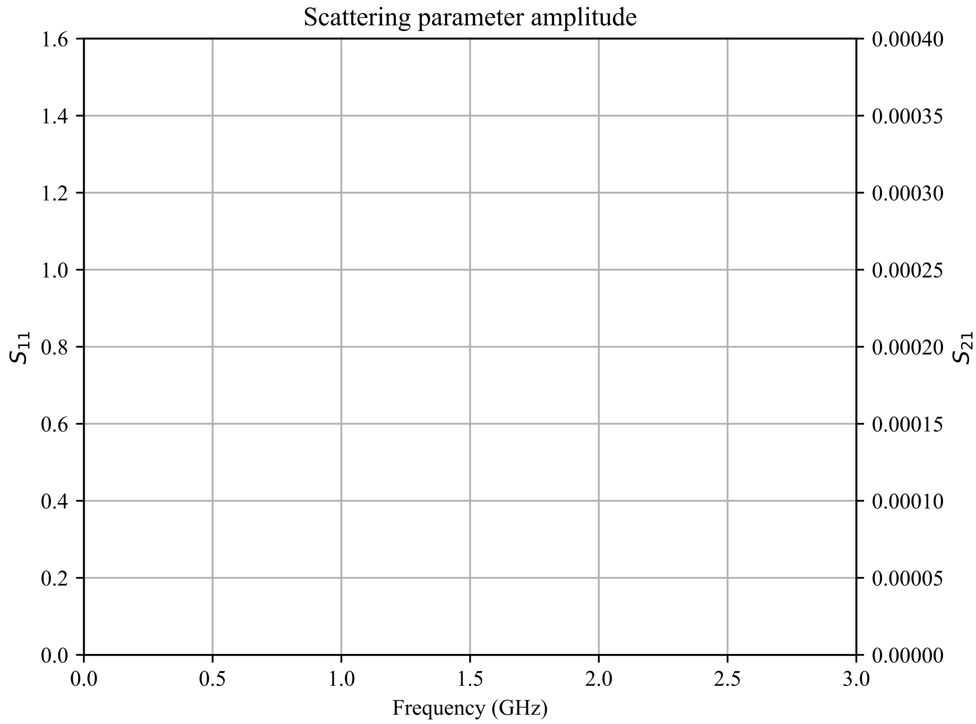

Figure 4: Actual uncalibrated scattering parameters (to be completed).

7. Explain the measurement in light of what you learnt on systematic and random errors, and the position of the calibration plane.

8. *(Lab)* Connect an SMA adapter to the cable connected to port 1. Perform open, short, and load calibration on port 1 by connecting the appropriate calibration standard to the SMA adapter (`Calibrate > Calibrate > Open`, then `Short`, then `Load`). Save the calibration in the second slot (`Calibrate > Save`). Make sure it is applied (`Calibrate > Apply` checked). There should be a vertical white `SOL` marking on the left of the screen.

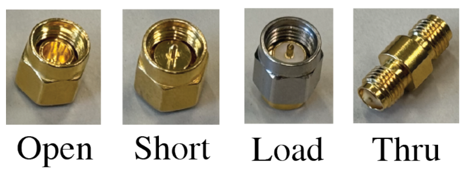

Figure 5: Calibration standards.

9. *(Lab)* Disconnect the load and sketch $|S_{11}|$ and $|S_{21}|$ in fig. 6.

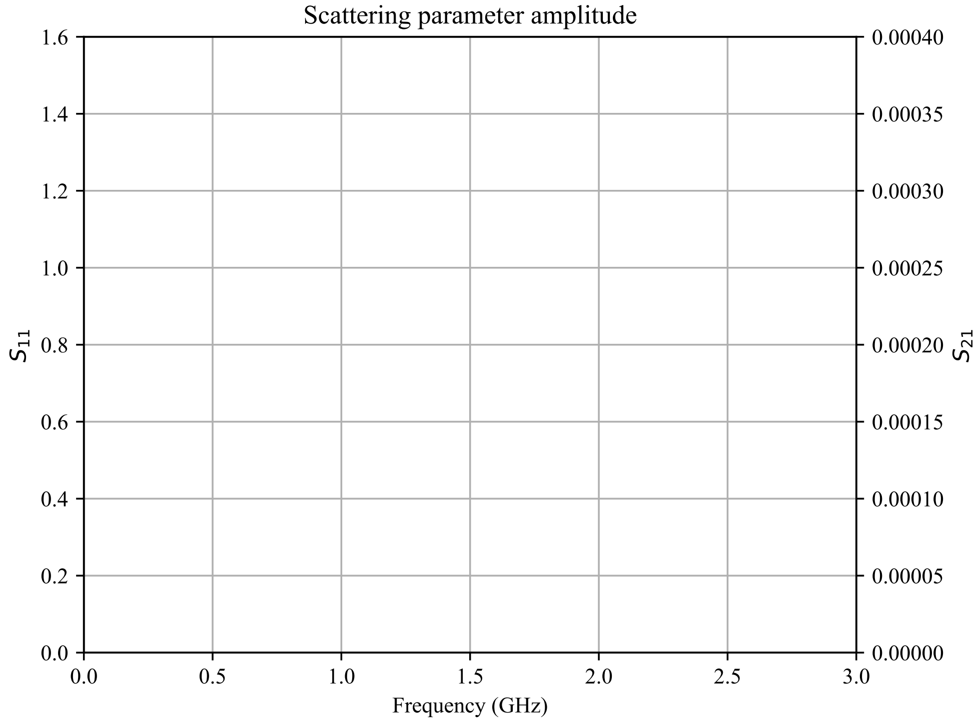

Figure 6: Scattering parameters, port 1 calibrated (to be completed).

10. Which systematic errors should be compensated so far?

11. Explain the measurement with port 1 calibrated:

12. *(Lab)* Connect the load to port 1 and perform the isolation calibration (`Calibrate > Calibrate > ISOLN`). Connect the through adapter and perform the through calibration (`Calibrate > Calibrate > Thru`). Be careful to minimize the bending of the coaxial cables. As before, save the calibration and make sure it is applied. A vertical white `SOLTX` marking should appear on the left side of the screen.

13. *(Lab)* Disconnect the through calibration standard so that both ports are left open.

14. *(Lab)* Sketch $|S_{11}|$ and $|S_{21}|$ in fig. 7.

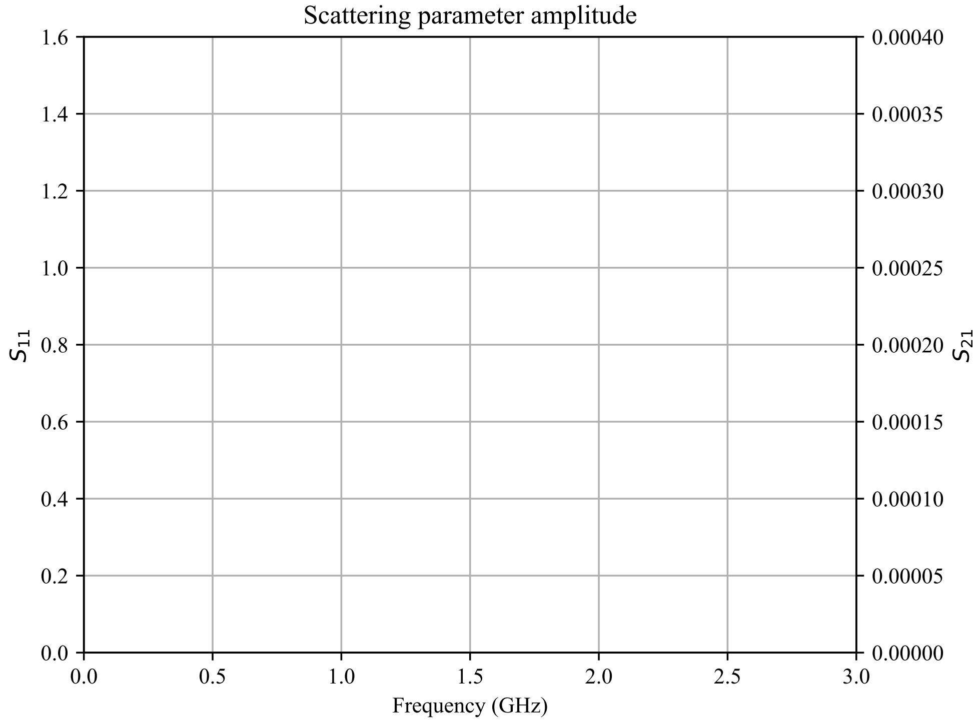

Figure 7: Scattering parameters, both ports calibrated (to be completed).

Congratulations, you have performed a one-way SOLTX[1] calibration!

15. *(Lab)* We now take interest in S_{21}. By visually checking the maximum amplitude of S_{21} (precision: half a vertical division, or 25µ), complete table 1 for various averaging with or without calibration. You can enable or disable the calibration in the Calibration menu (`Calibrate > Apply`). Change the averaging in `Display > AVG`.

Averaging	No calibration	With SOLTX calibration
None (1×)		
5×		
10×		

Table 1: Peak S_{21} amplitude.

16. What type of error does averaging mitigate?

17. Which types of systematic errors have an effect on S_{21}?

18. Do you see an improvement by using SOLTX calibration? Briefly motivate your answer.

[1] Short, Open, Load, Through, cross(X)coupling

2.2 Reflection and transmission parameters

1. *(Lab)* Make sure calibration is activated and averaging is disabled or set to $2\times$.
2. *(Lab)* Set all four traces as follows:
   - Trace 0: S_{11}, logmag, 10 dB/div
   - Trace 1: S_{21}, logmag, 20 dB/div
   - Trace 2: S_{11}, Smith (default)
   - Trace 3: S_{11}, phase, 90 °/div (default)
3. *(Lab)* Using the Smith chart, what reflection coefficient Γ (a complex number) do you obtain with the **open** calibration standard? You can read the number corresponding to the marker location on the top of the screen. Γ_{measured} = ______________. What do you expect? Γ_{expected} = ______________.
4. *(Lab)* As before, for a **short**: Γ_{measured} = ______________, Γ_{expected} = ______________.
5. *(Lab)* As before, for a matched **load**: Γ_{measured} = ______________, Γ_{expected} = ______________.
6. *(Lab)* Connect one blue SMA from port 1 to port 2, as in fig. 8(a).

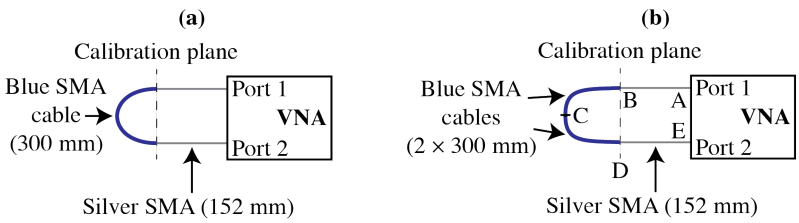

Figure 8: Cable transmission measurement setup. A-E: possible sources of reflections.

7. *(Lab)* Set trace 0 to measure S_{11} in logmag scale, 10 dB/div.
8. *(Lab)* Set trace 1 to measure S_{21} in logmag scale, 100 mdB/div.
9. *(Lab)* Note down S_{11} and S_{21} at 1 GHz by moving the marker (using the knob or the touchscreen) at the closest frequency. S_{11} = ______________dB, S_{21} = ______________dB.
10. *(Lab)* Based on the two values right above, what is the magnitude of the reflection coefficient at 1 GHz? $|\Gamma|$ = ______________dB.
11. What is the return loss (RL) of the cable at 1 GHz? RL = ______________dB.
12. *(Lab)* What is the voltage standing wave ratio (VSWR) of the cable at 1 GHz? VSWR = ______________.
13. *(Lab)* The cable manufacturer specifies a maximum VSWR of 1.3. Is this true in the frequency range 30 kHz to 3 GHz?

14. *(Lab)* The insertion loss (IL) of this cable describes the ratio of power available at the cable output to the cable input power. What is the insertion loss at 1 GHz? IL = ______________dB.
15. *(Lab)* Double the cable length, as in fig. 8(b). You need to use two SMA adapters and the through calibration standard. What is the insertion loss at 1 GHz? IL = ______________dB.
16. Shortly explain the change in insertion loss with the change in cable length.

If you do not attempt the next section (Bonus), please skip to section 2.4.

2.3 Bonus: Time-domain measurements

Due to time constraints, this section is optional and will count only as bonus points.

1. *(Lab)* Disable traces 2 and 3 in `Display > Trace`.
2. *(Lab)* Disconnect the blue SMA cables from port 1.
3. *(Lab)* Activate the inverse Fourier transform (`Display > Transform > Transform off`). Keep a bandpass transform, a normal window, and a velocity factor (ratio of actual speed of light to that in vacuum) of 70%.
4. *(Lab)* Set trace 0 to show the real part of S_{11}, 250m/div, and trace 1 to S_{21} in a linear scale, 125m/div.
5. *(Lab)* Set the number of samples to 256 (`Stimulus > CFG sweep > Sweep points`).
6. *(Lab)* Complete fig. 9 below with a sketch of the reflection waveform (S_{11}) only (do not copy S_{21}). Indicate the waveform with "open."

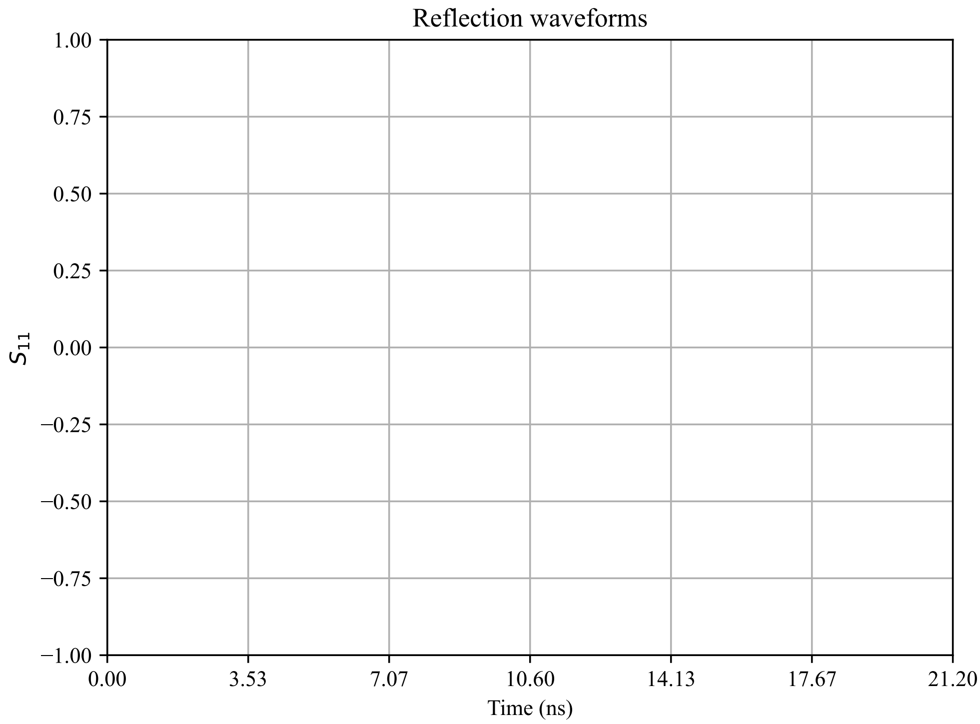

Figure 9: Open, short, and load reflection waveforms (to be completed).

7. *(Lab)* Connect the **short** calibration standard. Complete fig. 9 with a sketch of the corresponding reflection waveform, and indicate the plot with "short."
8. *(Lab)* Connect the matched **load** calibration standard. Complete fig. 9 with a sketch of the corresponding reflection waveform, and indicate the plot with "load."
9. Explain the shape (in particular, the polarity) in all three cases.

10. *(Lab)* Connect both blue SMA cables as before between ports 1 and 2.
11. *(Lab)* Change trace 0 to show a linear scale with 5m/div.

12. *(Lab)* Complete fig. 10 with sketches of the measured waveforms (S_{11} and S_{21}).

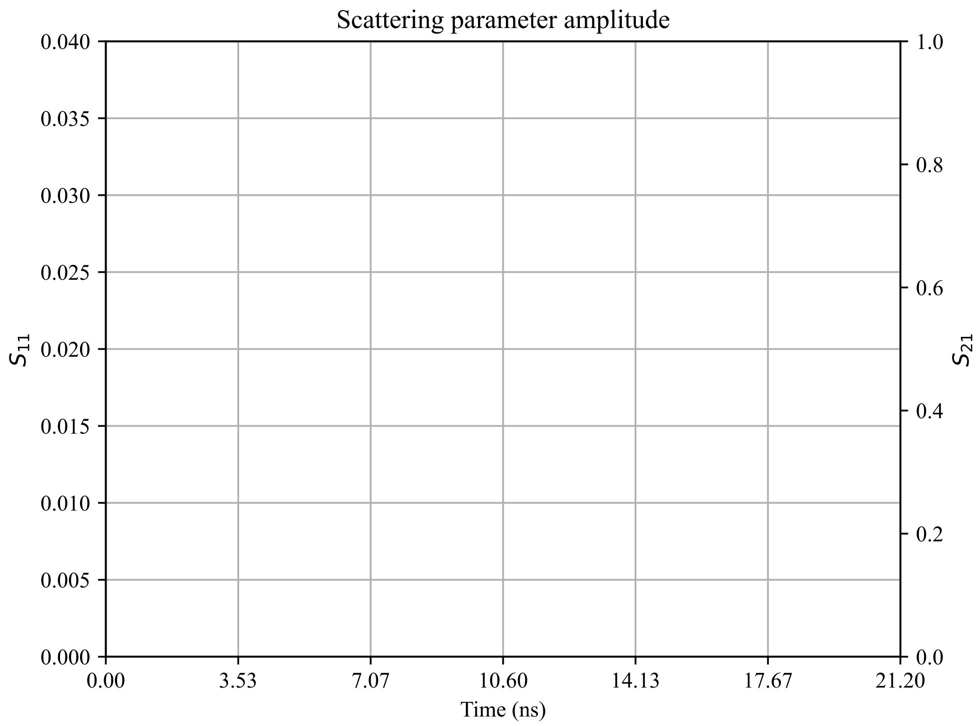

Figure 10: Cable reflection and transmission waveforms (to be completed).

13. Explain the transmission waveform. In particular, verify that the timing of the waveform matches what you expect. You can move the cursor to locations of peaks to determine the timing or the distance (pay attention to the factor 2 introduced by the LiteVNA time-to-distance conversion).

14. Explain the reflection waveforms: label all reflections with the corresponding letter in fig. 8b.

2.4 Before you leave

(Lab) Before you leave the laboratory, complete the following checklist to make sure you return all the received equipment:

- ☐ LiteVNA
- ☐ User interface reference sheet
- ☐ Strap
- ☐ 2 blue SMA RF cables
- ☐ 2 silver SMA RF cables
- ☐ 2 SMA through adapters
- ☐ Calibration kit:
  - ☐ Through
  - ☐ Load
  - ☐ Short
  - ☐ Open
- ☐ USB cable
- ☐ USB power brick