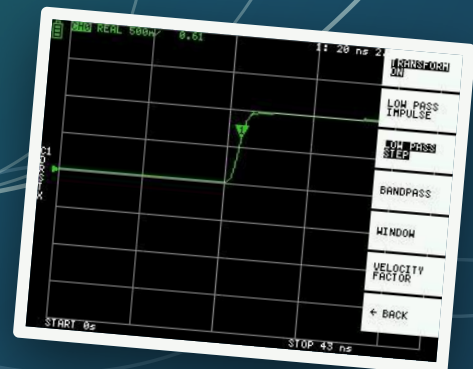
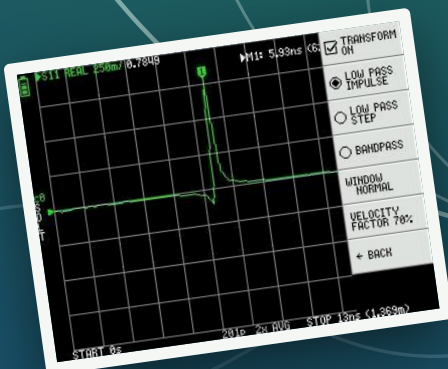
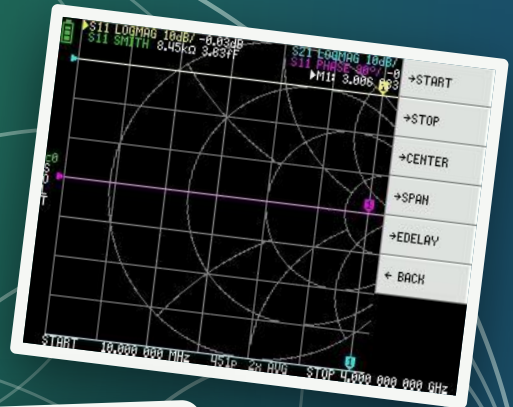


LITEVNA practical course

Calibration · matching · filters · TDR · crystals



LiteVNA — practical course

Measurement exercises with detailed step-by-step procedures, adapted to the LiteVNA family running Dislord/LiteVNA firmware.

EQUIPMENT AND FIRMWARE ASSUMED IN THIS COURSE

Device	LiteVNA (LiteVNA62 / LiteVNA64), SMA female connectors on both ports
Firmware	Dislord/LiteVNA firmware (menu structure as in the user manual for v1.2–v1.4, same code base as DiSlord/NanoVNA-D)
Frequency range	50 kHz – 6.3 GHz
Measurement points	21–1001 points on the device (up to 65535 over USB)
Calibration kit	Open/Short/Load/Thru with male SMA (the ports are female)

The main menu opens when you press the jog wheel, or when you tap anywhere on the screen that is not a marker. It shows seven fixed main items:

- **DISPLAY** — trace format, channel (S11/S21), scale, time domain (TRANSFORM)
- **MARKER** — select/move markers, set START/STOP/CENTER/SPAN/E-DELAY from a marker
- **STIMULUS** — START/STOP/CENTER/SPAN/CW FREQ, number of points (CFG SWEEP)
- **CALIBRATE** — RESET, calibration sequence (OPEN/SHORT/LOAD/ISOLN/THRU/DONE), SAVE, CORRECTION
- **RECALL** — load a saved calibration/setup (slot 0–6, or from a file on the SD card)
- **SD CARD** — save a screenshot (BMP) or measurement data (S1P/S2P) to the MicroSD card
- **CONFIG** — touchscreen calibration, brightness, version, firmware update

Numbers are entered on a numeric keypad with unit keys **G** / **M** / **k** / **×1** that multiply and confirm the value in the same keypress (e.g. **1** **4** **M** = 14 MHz).

UPDATING THE FIRMWARE (RECOMMENDED BEFORE YOU START)

Make sure your LiteVNA is running the latest firmware before you begin the course — newer firmware fixes bugs and in some cases has different menu choices than those described in this document.

1. Download and install the PC program **NanoVNA-App**, and download the latest firmware file for your exact model (LiteVNA62, LiteVNA64 or LiteVNA67 — the firmware is not shared between the models). Both can be downloaded from <https://www.zeenko.tech/litevna>.
2. Start NanoVNA-App on the PC.
3. Connect the LiteVNA to the PC with a USB cable.
4. Hold the jog wheel (the rocker switch) pressed in while you switch the device on — this puts the LiteVNA in update mode. The screen stays black; this is normal and expected.
5. In Windows **Device Manager**, check which COM port the device is connected to.
6. In NanoVNA-App: select the correct COM port from the drop-down menu at the top left of the window.
7. A window appears saying that the device has older firmware. Follow the instructions in the window to upload the new firmware file, and restart the device when the update has finished.
8. Confirm the new version on the device: `CONFIG → VERSION`.

Alternative way to start an update

If the device is already switched on, you can instead go to `CONFIG → BOOTLOAD → RESET AND ENTER` to put it in update mode — then you do not have to power-cycle it with the jog wheel held in.

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4. Identifying an unknown component **Easy**
5. Characteristic impedance of a cable (quarter-wave resonance) **Easy**
6. Matching an antenna **Intermediate**
7. Building and measuring a "dummy antenna" (too-long vertical) for matching practice **Intermediate**
8. Using measurement data in an external program — Smith chart and matching with an S1P file **Intermediate**
9. Resonant frequency and Q of a trap **Intermediate**
10. Characterizing a filter **Intermediate**
11. Measuring an L/C component and its self-resonance **Intermediate**
12. Measuring a balun/common-mode choke **Intermediate**
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Exercise 1 — Calibration (reflection and transmission)

Easy

Goal: Learn to calibrate the LiteVNA correctly for both 1-port reflection measurements (S11) and 2-port transmission measurements (S21), so that the measurements that follow are accurate.

EQUIPMENT

- LiteVNA (62/64), SMA female connectors
- Calibration kit: Open, Short, Load (male SMA)
- Thru adapter/cable for the transmission calibration
- Optionally, short good-quality cables/adapters that will be used later in the course

A. Preparation

1. Switch on the LiteVNA and let it warm up/stabilize for 1–2 minutes (important for a stable oscillator and an accurate calibration).
2. Decide on the frequency range you will work in for the rest of the course (e.g. 1–30 MHz for HF). The calibration is valid *only* within the range it was made in.
3. Open the main menu and set `STIMULUS → START` and `STIMULUS → STOP` (or `CENTER / SPAN`), preferably with a little margin beyond what you actually need.
4. Set the number of measurement points high for good resolution: `STIMULUS → CFG SWEEP`. The LiteVNA supports 21–1001 points on the device — use 401–1001, balanced against sweep speed.
5. Decide where the "reference plane" is to be — i.e. which point in the cable is to count as "0". Use the same cables/adapters in the calibration as you will use in the actual measurement afterwards.

Key principle

The calibration removes error contributions from cables and adapters *up to* the point where the calibration standards are connected. If you change a cable or adapter after calibrating, the calibration is invalid. The LiteVNA computes interpolated calibration values if you change the frequency range afterwards, but this is less accurate than recalibrating.

B. Reflection calibration (S11) — OSL

1. Open `CALIBRATE → RESET` to clear any previous calibration.
2. Open `CALIBRATE` again to start the calibration sequence itself (the submenu now shows OPEN/SHORT/LOAD/ISOLN/THRU/DONE).
3. Connect the **Open** standard to port 1 (CH0). Press `OPEN` and wait until the step has finished — the marker moves automatically to the next step.
4. Connect the **Short** standard to port 1. Press `SHORT` and wait until the step has finished.
5. Connect the **Load** (50 Ω) standard to port 1. Press `LOAD` and wait until the step has finished.
6. Leave the Load connected to port 1 and press `ISOLN` (isolation measurement — reduces errors from leakage between the ports and is important for an accurate S21 later).

7. If you will *only* make reflection measurements: press **DONE** now and go to part D.

C. Transmission calibration (S21) — add Thru

1. Connect port 1 and port 2 together with the Thru adapter/cable.
2. Press **THRU** and wait until the step has finished.
3. Press **DONE** to compute and activate the full 2-port calibration.

D. Save and verify

1. After **DONE** a save menu appears — choose either a memory slot (0–6; slot 0 is loaded automatically at the next power-up) or save to a file on the SD card with a name of your own choosing. A file name on the SD card is useful for describing what the calibration actually applies to (e.g. cable type or measurement setup), since the memory slots only show the start/stop frequency. Note down/name clearly which saved calibration applies to which frequency range/setup.
2. Verify the reflection calibration: connect the Load to port 1 again. Set **DISPLAY → FORMAT → SMITH** — the point should stay clustered near the centre (50 Ω) over the whole frequency range.
3. Verify with Open/Short: the points should lie right out at the edge of the Smith chart (the right and left side respectively).
4. Verify the transmission calibration: connect port 1 and port 2 together again with the Thru. Set **DISPLAY → CHANNEL → S21** and **DISPLAY → FORMAT → LOGMAG** — S21 should now show ~0 dB, flat across the whole band.
5. Later in the course: use **RECALL → RECALL n** to bring back the correct calibration slot, or **RECALL** from the SD card, for the exercise you are working on.

E. Moving the calibration plane (E-DELAY)

If you are going to measure an antenna through a long feed line, it is best to calibrate at the end of the cable (at the antenna). If that is impractical (e.g. a permanently installed cable), you can instead move the reference plane electronically with **DISPLAY → SCALE → E-DELAY**.

Important: the value you enter is *time* (seconds, using the keypad prefixes for n/p), not millimetres or centimetres directly — there is no separate distance entry for the calibration plane. For S11 (reflection) this is a **round-trip** delay, since the signal travels out and back through the extra piece of cable:

$$\tau = 2 \cdot L \cdot VF / c$$

where L is the desired one-way shift of the reference plane (metres), VF is the velocity factor of the piece of cable, and c = 299,792,458 m/s. **Example:** 15 mm of extra RG58 cable (VF = 0.66):

$$\tau = 2 \cdot 0.015 \cdot 0.66 / 299,792,458 \approx 66 \text{ ps}$$

Then enter about **66p** (or **0.066n**) in the **E-DELAY** field.

Practical shortcut (often more accurate than a ruler-based calculation, since it compensates for the actual electrical length instead of an assumed VF): connect an **OPEN** or **SHORT** standard right at the new desired plane, set **DISPLAY → FORMAT → SMITH**, place a marker, and use **MARKER → OPERATIONS → E-DELAY** — this sets E-DELAY automatically so that the phase at the marker frequency is nulled out. Adjust until the whole curve collapses to a single point out at the edge of the Smith chart (purely resistive/reactance-free across the whole band). You have then compensated exactly for the actual electrical length, regardless of inaccuracies in the stated VF or connector effects.

Tip

CALIBRATE → CORRECTION lets you temporarily switch error correction on/off so you can compare an uncalibrated and a calibrated measurement.

Exercise 2 — Measuring the SWR of an antenna

Easy

Goal: Measure the standing wave ratio (SWR/VSWR) of an antenna across the desired frequency band, and find the resonant frequency.

EQUIPMENT

- LiteVNA, calibrated for reflection (S11) in the right frequency range (see Exercise 1)
- The antenna to be measured, with its feed line/cable
- Optionally a balun/unun if the antenna needs one

1. Bring up the correct calibration with `RECALL → RECALL n`, or recalibrate for exactly this band with finer resolution (see Exercise 1).
2. Connect the antenna's feed line directly to port 1 (CH0) on the LiteVNA.
3. Set `STIMULUS → START / STOP` to cover the whole band of interest, plus a little margin on each side (e.g. $\pm 10\text{--}20\%$).
4. Set `DISPLAY → CHANNEL → S11` and `DISPLAY → FORMAT → SWR`.
5. Adjust the scale of the SWR axis via `DISPLAY → SCALE`, e.g. 1–5 or 1–10, so that the curve becomes readable.
6. Look for the dip (minimum) in the SWR curve — this is the antenna's resonant frequency.
7. Use `MARKER → SELECT MARKER` to place one point at the lower band edge, one at the desired centre frequency, and one at the upper band edge. Read the SWR value at each point in the status line at the top.
8. Compare the SWR you read with the acceptable limit for your purpose (typically $\text{SWR} \leq 2:1$, often 1.5:1 or better is wanted).
9. If possible, move the antenna/test setup (height, distance to ground/objects) and repeat the measurement to see how sensitive the resonance is to the surroundings.
10. Save the result via the `SD CARD` menu: a screenshot (BMP) and/or measurement data as an S1P file for further analysis in a computer program (e.g. NanoVNA-Saver or NanoVNA-App).

Pitfall: long cable

A long and/or lossy feed line between the LiteVNA and the antenna can "mask" a poor SWR and show a better number than what actually exists at the antenna. Measure as close to the antenna as practical, or correct for cable loss/length (see Exercise 3).

Tip

If the dip lies outside the desired band, the antenna should be shortened (dip too low in frequency → shorten) or lengthened (dip too high in frequency → lengthen) — see Exercise 6 for more.

Exercise 3 — Measuring cable attenuation (loss)

Easy

Goal: Determine the attenuation (loss) of a coaxial cable at a given frequency, to judge whether the cable is suitable for the purpose (e.g. a long feed line to an antenna).

EQUIPMENT

- LiteVNA, calibrated for reflection (S11) and/or transmission (S21)
- The cable to be tested
- Short-circuit standard, plus adapters that fit the cable's connectors

A. Simple method (1 port, open/shorted end)

1. Calibrate the LiteVNA for reflection (S11) at the near end of the cable.
2. Connect the test cable to port 1 and leave the far end open or shorted.
3. Set `DISPLAY → FORMAT → LOGMAG` and read S11 in dB at the desired frequency. Preferably make the measurement with both an open and a shorted end and use the average, for better accuracy.
4. Calculate the one-way attenuation: the signal passes through the whole cable twice (in and reflected back),

so
$$A(\text{dB}) = -S11(\text{dB}) / 2$$

5. Divide by the length of the cable in metres to get the attenuation in dB/m, and compare with the data sheet for the cable type.

B. Accurate method (2 ports, thru measurement)

1. Calibrate for transmission (S21) without the test cable (thru with short adapters directly between port 1 and port 2), see Exercise 1.
2. Insert the test cable between port 1 and port 2.
3. Set `DISPLAY → CHANNEL → S21`, `FORMAT → LOGMAG` and read S21 directly in dB — this is the total attenuation through the whole length of the cable at this frequency.
4. Divide by the length to get dB/m and compare with method A and the data sheet.

Pitfall

Method A can give noise/ripple on short cables because the direct and reflected signals interfere — average over a small frequency window if needed. Also make sure the connectors are clean and screwed on tightly; a poor contact gives extra, false attenuation.

Exercise 4 — Identifying an unknown component

Easy

Goal: Determine whether an unknown, unmarked component is a resistor, an inductor or a capacitor, and estimate an approximate value — solely by looking at how the reactance behaves with frequency.

EQUIPMENT

- LiteVNA, calibrated for reflection (S11)
- A simple test fixture/adaptor for connecting a component as a shunt to ground on port 1 (as in Exercise 11)
- Some unknown/unmarked components (resistor, inductor, capacitor)

1. Calibrate **CALIBRATE** for S11.
2. Connect the component as a shunt to ground on port 1.
3. Set **DISPLAY → FORMAT → REACTANCE** as the active trace, preferably with **RESISTANCE** on an extra trace.
4. Set a wide frequency range (e.g. 1–30 MHz for HF components).
5. Look at how the reactance X behaves:
 - $X \approx 0$ across the whole band, R approximately constant → **resistor**
 - X positive and increasing with frequency → **inductor**
 - X negative and becoming more negative (decreasing in magnitude) with frequency → **capacitor**
6. Confirm with two markers at different frequencies f_1 and f_2 (e.g. with $f_2 = 2 \cdot f_1$): if $|X|$ roughly doubles when the frequency doubles, the component is inductive ($X \propto f$); if $|X|$ roughly halves when the frequency doubles, it is capacitive ($X \propto 1/f$).
7. Calculate an approximate component value from the X you read at one of the frequencies:

$$\begin{aligned}\text{Inductor: } L &= X / (2\pi f) \\ \text{Capacitor: } C &= 1 / (2\pi f \cdot |X|)\end{aligned}$$

8. Compare with any colour code or printed value on the component, if available, as the answer key.

Tip

Adapt the frequency range to the size of the component: a small capacitor (a few pF) can look almost "open" (very high $|X|$) across the whole HF range, while a large inductor (many μH) can look almost shorted at low frequencies. Extend the frequency range upwards if the reactance looks suspiciously constant near one extreme.

Pitfall

Near the self-resonant frequency (SRF), both inductors and capacitors apparently switch "type" (see Exercise 11 for why) — do this test at a frequency well below the expected SRF for a reliable result.

Exercise 5 — Characteristic impedance of a cable (quarter-wave resonance)

Easy

Goal: Determine a cable's characteristic impedance (Z_0) — useful for identifying an unknown/unmarked cable type, or verifying that a cable really is $50\ \Omega$.

EQUIPMENT

- LiteVNA, calibrated for reflection (S11)
- The cable to be tested, with a free (open) end — plus the ability to short the same end (Method B)

Method A: Quarter-wave resonance (halved frequency)

Background

An open cable behaves as a pure reactance that alternates between capacitive and inductive with frequency. At a quarter wavelength (and odd multiples of it) the cable becomes resonant, and the impedance falls to a local *minimum* — a small, almost purely resistive value (depending on the cable's loss),

not

the characteristic impedance. This frequency is still useful as a reference point: if you halve it, the cable is now only

1/8 wavelength

long, and there the impedance becomes almost purely reactive with an absolute value very close to Z_0 :

$Z_0 \approx \sqrt{R^2 + X^2}$ (measured at half the quarter-wave resonant frequency, not at the resonance itself)

1. Calibrate **CALIBRATE** for S11.
2. Connect the cable to port 1 and leave the other end open.
3. Set **DISPLAY → FORMAT → |Z|** (or show RESISTANCE and REACTANCE on separate traces).
4. Set a frequency range wide enough to catch at least one clear quarter-wave resonance — for a typical 20–30 m cable it is often somewhere in the HF range; try e.g. 1–30 MHz and look for a clear dip in $|Z|$.
5. Find the frequency f_1 where $|Z|$ has a clear local minimum (close to zero, purely resistive) — this is the quarter-wave resonance. You do not need to know the cable's physical length or VF for this; it is simply 1/4 wavelength at exactly this frequency.

6. Set a marker (or **STIMULUS → CW FREQ**) to exactly **half**: $f_2 = f_1 / 2$. At f_2 the cable is only 1/8 wavelength long.

7. Read R and X at f_2 , and calculate: $Z_0 = \sqrt{R^2 + X^2}$

8. Compare the result with known standard values — 50 Ω (RG-58, RG-213 and most amateur radio cables) or 75 Ω (RG-59, RG-6, TV cable) — to identify the cable type.

Example (from PA3A's measurements of RG-58, source: [Measurements-With-The_nanoVNA.pdf](#)): at f_2 (1/8 wavelength) the reading is $R = 5 \Omega$, $X = 53 \Omega$:

$$Z_0 = \sqrt{5^2 + 53^2} = \sqrt{2834} \approx 53.2 \Omega \quad (\text{Belden RG-58/U is specified as } 53.9 \Omega - \text{very close})$$

Pitfall

Do not read R/X at the resonant frequency f_1 itself — there the impedance is low and gives a completely wrong (too low) Z_0 . It is precisely at the *halved* frequency f_2 that the measurement is to be made. For long cables f_2 may end up below the LiteVNA's minimum frequency of 50 kHz (see Exercise 1) — in that case use a shorter piece of cable, or measure at 3/8, 5/8 etc. wavelength instead (odd multiples of 1/8 give the same result, just find the corresponding quarter-wave resonance higher up and halve it).

Method B: Open and shorted end, same frequency

Background

This is another classic technique, and an exact identity — it works at *any* frequency, not only at special resonance points as in Method A. For an open cable the input impedance is $Z_{\text{open}} = Z_0 \cdot \coth(\gamma L)$, and for a shorted cable it is $Z_{\text{short}} = Z_0 \cdot \tanh(\gamma L)$ (γ is the propagation constant, L the length of the cable). Since $\coth(x) \cdot \tanh(x) = 1$ whatever x is, the length and loss terms cancel out completely when you multiply the two together:

$$Z_{\text{open}} \cdot Z_{\text{short}} = Z_0^2 \implies Z_0 = \sqrt{Z_{\text{open}} \cdot Z_{\text{short}}}$$

About the arithmetic rules — is this the difference of squares?

No, not for the multiplication itself. The difference-of-squares identity, $(a+b)(a-b) = a^2 - b^2$, applies when you multiply a complex number by its *own conjugate* — and that is in fact exactly what happens

when you calculate $|Z| = \sqrt{R^2 + X^2}$ in Method A and elsewhere in the course: $(R+jX)(R-jX) =$

$R^2 - (jX)^2 = R^2 + X^2$, since $j^2 = -1$. But Z_{open} and Z_{short} are two *independent* measurements, not conjugates of each other, so you must use the general rule for multiplying complex numbers (ordinary expansion, with $j^2 = -1$):

$$(R_1 + jX_1)(R_2 + jX_2) = (R_1R_2 - X_1X_2) + j(R_1X_2 + R_2X_1)$$

Taking the square root of this complex result requires converting to polar form (magnitude and angle) first — more work than necessary when all we really want is the numerical value of $|Z_0|$.

Shortcut: skip the complex arithmetic

For complex numbers, $|A \cdot B| = |A| \cdot |B|$ always holds. Since $Z_{\text{open}} \cdot Z_{\text{short}} = Z_0^2$ exactly, it follows that:

$$|Z_0| = \sqrt{(|Z_{\text{open}}| \cdot |Z_{\text{short}}|)}$$

So you can calculate $|Z_{\text{open}}| = \sqrt{R_1^2 + X_1^2}$ and $|Z_{\text{short}}| = \sqrt{R_2^2 + X_2^2}$ separately (just as in Method A), and take the square root of the product of the two — without having to multiply or take the square root of complex numbers at all.

1. Calibrate **CALIBRATE** for S11.
2. Choose an **arbitrary** frequency f — this method requires no special resonance, unlike Method A.
3. Connect the cable to port 1 with the end open. Read R_1 and X_1 at f , and calculate

$$|Z_{\text{open}}| = \sqrt{R_1^2 + X_1^2}.$$

4. Short the same cable end (without changing the length of the cable or the rest of the setup), and measure again at the **same** frequency f . Read R_2 and X_2 , and calculate

$$|Z_{\text{short}}| = \sqrt{R_2^2 + X_2^2}.$$

5. Calculate the characteristic impedance: $Z_0 = \sqrt{(|Z_{\text{open}}| \cdot |Z_{\text{short}}|)}$

6. Compare with known standard values (50 Ω / 75 Ω), as in Method A.

Example (illustrative numbers, not from a real measurement): at f the readings are $R_1=15\ \Omega$, $X_1=-40\ \Omega$ (open) and $R_2=20\ \Omega$, $X_2=65\ \Omega$ (shorted):

$$|Z_{\text{open}}| = \sqrt{(15^2 + 40^2)} \approx 42.7\ \Omega$$

$$|Z_{\text{short}}| = \sqrt{(20^2 + 65^2)} \approx 68.0\ \Omega$$

$$Z_0 = \sqrt{(42.7 \cdot 68.0)} \approx 53.9\ \Omega$$

Pitfall

The length/connection of the cable must be completely unchanged between the two measurements — only short/open the end itself, do not reconnect the rest of the setup. The calibration reference plane must also be the same for both measurements. Method B is most accurate when the cable is not too short (a few wavelengths or more), since a very short cable gives little difference between Z_{open} and Z_{short} and therefore more sensitivity to reading errors.

Exercise 6 — Matching an antenna

Intermediate

Goal: Use the LiteVNA to find the antenna's impedance, understand the deviation from $50\ \Omega$, and adjust/match the antenna so that the SWR becomes acceptable at the desired frequency.

EQUIPMENT

- LiteVNA, calibrated for reflection in the relevant band
- The antenna to be matched
- Tools for physical adjustment (cutting/extending the radiator) and/or components for a matching network (variable capacitor, inductor, or an antenna tuner)

1. Calibrate the LiteVNA for reflection (S11) in the frequency range around the desired operating frequency (see Exercise 1).
2. Connect the antenna to port 1. Set up two traces: `DISPLAY → TRACES → TRACE 0` with `FORMAT → SMITH`, and `TRACE 1` with `FORMAT → SWR`, both on channel S11.
3. Place a marker on the desired operating frequency. Read the impedance directly as resistance and reactance by switching the active trace to `FORMAT → RESISTANCE` and `FORMAT → REACTANCE` (ohms per division; the numerical value is shown in the status line for the active marker).
4. Interpret the result:
 - Positive reactance (+jX, inductive) → the antenna is electrically too long
 - Negative reactance (−jX, capacitive) → the antenna is electrically too short
 - R far from $50\ \Omega$ → the radiation resistance/the setup itself causes a mismatch (height above ground, ground plane, feed point etc.)
5. Simplest measure — physical length adjustment:
 - If the antenna is too long (inductive): cut a little off the radiator (a few cm at a time) and measure again.
 - If the antenna is too short (capacitive): extend the radiator and measure again.
 - Repeat in small steps — the impedance can change quickly per cm, especially on the higher bands.
6. If physical adjustment is not possible or not enough, use a matching network (L-network) between the transmitter/cable and the antenna:
 - Use the Smith chart to determine whether you need a series component (inductor/capacitor) and a parallel component to "move" the impedance point towards the centre ($50\ \Omega$).
 - Insert a variable capacitor and/or inductor (or an antenna tuner) in the signal path.
7. Adjust the components while monitoring the SWR/Smith chart in real time, until the impedance point lies as close as possible to the centre of the Smith chart at the operating frequency.
8. Check the SWR across the *whole* band after matching — a good match at one point can give a narrower bandwidth than desired.
9. Document the final component values (or the physical length) for the antenna, so that the setup is reproducible.
10. Be aware that a matching network can introduce loss, especially with low-Q components — a physically correct length is always preferable where practical.

Bonus: calculate the L-network analytically (instead of pure trial and error)

Step 6 above can be done faster by calculating the starting component values in advance, instead of going straight to trial and error with a variable capacitor/inductor. Procedure, with R and X read from step 3:

1. First neutralize the reactance X with a series component of the opposite sign, so that what remains is a pure resistance R:

- X positive (inductive): series capacitor with $X_C = X$

- X negative (capacitive): series inductor with $X_L = |X|$

2. Then calculate the L-section that is to transform the remaining resistance R to 50 Ω . The low-pass variant (series inductor + parallel capacitor) is normally preferable, since it also attenuates harmonics/noise:

$$Q = \sqrt{(Z_{\text{high}} / Z_{\text{low}} - 1)}$$

where Z_{high} is the larger of R and 50 Ω , and Z_{low} is the smaller. The series inductor is placed on the low-impedance side, the parallel capacitor on the high-impedance side:

$$\begin{aligned} X_L &= Q \cdot Z_{\text{low}} \\ X_C &= Z_{\text{high}} / Q \end{aligned}$$

3. Convert to component values at the operating frequency f: $L = X_L / (2\pi f)$ and

$$C = 1 / (2\pi f \cdot X_C)$$

4. Use these values as the starting point in steps 6–7 above — then fine-tune while monitoring the Smith chart, since the R/X you read and real component values always deviate a little from the ideal.

Example: antenna with $R = 25 \Omega$, $X \approx 0$ (already resonant) at 14.2 MHz. $Z_{\text{high}} = 50 \Omega$, $Z_{\text{low}} = 25 \Omega$:

$$\begin{aligned} Q &= \sqrt{(50/25 - 1)} = \sqrt{1} = 1 \\ X_L &= 1 \cdot 25 = 25 \Omega \rightarrow L \approx 280 \text{ nH} \\ X_C &= 50 / 1 = 50 \Omega \rightarrow C \approx 224 \text{ pF} \end{aligned}$$

Tip

The LiteVNA sweeps continuously in normal operation, so you see the change in real time as you turn a variable capacitor/inductor. Use **PAUSE SWEEP** (checkbox at the bottom of the main menu) if you want to freeze a picture for reading.

Exercise 7 — Building and measuring a "dummy antenna" (too-long vertical) for matching practice

Intermediate

Goal: Build a compact, reproducible dummy load (DUT — Device Under Test) that at 14.2 MHz presents a representative, inductive feed-point impedance such as is typically seen on an electrically too-long vertical antenna, measure it with the LiteVNA, and use it as a fixed test object for matching-network design (cf. Exercise 6) — without having to build/adjust a real antenna.

EQUIPMENT

- LiteVNA, calibrated for reflection (S11) around 14 MHz
- SMA male connector intended for direct soldering (not cable-mounted), since the LiteVNA's ports are female
- One non-inductive SMD resistor (carbon/thick film, 0603/0805), approx. 47–56 Ω
- One small air-core or low-loss inductor, approx. 2.2–3.3 μH (home-wound or a fixed-value choke with low self-capacitance)
- Soldering equipment, optionally thin copper wire for winding the inductor yourself
- Optional: a small metal enclosure (e.g. a piece of copper tube or a die-cast box) for mechanical protection/shielding

Background

As explained in Exercise 6: an antenna that is electrically *too long* (longer than the resonant length) shows positive (inductive) reactance at the feed point, while the resistance often still lies somewhere near 50 Ω . This DUT represents exactly such a situation — a generic, moderately too-long vertical antenna — with typical example figures

$R \approx 50 \Omega$, $X \approx +250 \Omega$

, simulated with a simple series circuit of one resistor and one inductor.

Note:

this is *not* meant to represent a $5/8\lambda$ vertical specifically. A real $5/8\lambda$ (0.625λ) vertical is actually **capacitive**

at the feed point (typically $R \approx 40\text{--}60 \Omega$, $X \approx -200$ to -300Ω) — confirmed in the ARRL/QST article "Constructing a Simple 5/8-Wavelength Vertical Antenna for 2 Meters" (E. J. Bauer, W9WQ): "The feed-point impedance of a $5/8\lambda$ vertical antenna exhibits a resistive component in the vicinity of 50 ohms. It requires a suitably chosen series inductor [...] to cancel the capacitive reactance which also exists at that point." That is exactly why commercial $5/8\lambda$ verticals have an inductive matching coil at the base. This DUT (with its inductive reactance) is, on the other hand, well suited for practising the matching of an antenna that has simply been set up *somewhat too long* — a very common practical situation.

A. Calculate the target impedance and component values

1. Decide on a design frequency, e.g. **14.20 MHz** (in the middle of the part of the 20 m band you are interested in).

2. Use a representative example of the feed-point impedance of a moderately too-long vertical antenna as the target: $R \approx 50 \Omega$, $X \approx +250 \Omega$ (inductive).
3. Calculate the inductance required for the desired reactance at the design frequency:

$$L = X / (2\pi f)$$

$$L = 250 / (2\pi \cdot 14.2 \cdot 10^6) \approx 2.8 \mu\text{H}$$

4. Choose the nearest achievable component values, e.g. $R = 50 \Omega$ (or the nearest E12 value, $47 \Omega/56 \Omega$) and $L \approx 2.7\text{--}3.3 \mu\text{H}$.

Desired reactance X	Required L at 14.2 MHz
+200 Ω	$\approx 2.2 \mu\text{H}$
+250 Ω	$\approx 2.8 \mu\text{H}$
+300 Ω	$\approx 3.4 \mu\text{H}$

Pitfall: this is an illustrative example, not a specification

The values above were chosen as a representative, round example of a moderately too-long vertical antenna — they are *not* taken from one specific, documented antenna length or type, and the actual feed-point impedance of a real antenna depends strongly on exact length, ground plane/radials, mast diameter and mounting height. If you need an accurate figure for your own antenna, you should model it in a NEC-based program (e.g. 4NEC2) or measure it directly, rather than rely on this table.

B. Building the DUT (Device Under Test)

SMA centre pin —[R]—[L]— SMA shield/flange (ground)
(short, straight series chain – no loops)

1. Use an SMA male connector where the centre pin is freely accessible for direct soldering (not a ready-made cable-mounted connector).
2. Solder the resistor directly onto the centre pin, with the shortest possible solder lead — preferably under 3 mm from the pin tip to the resistor's leg. This is the R part of the series chain.
3. Solder the inductor in series right after the resistor, and terminate the other end of the inductor directly on the connector's shield/flange (ground), again with the shortest possible distance.
4. Make sure the whole R–L chain forms a straight, short "bridge" between centre pin and shield — avoid loops or bent, long wire stubs, since these add parasitic inductance/capacitance that shifts the DUT's impedance away from the calculated value.
5. Preferably mount the assembly inside a small metal enclosure around the SMA connector (e.g. a short piece of copper tube or a small die-cast box) — this gives mechanical protection and prevents your hand from detuning the measurement when you hold the DUT.
6. Label the DUT clearly with the component values and design frequency, e.g. $R=50\Omega$, $L=2.8\mu\text{H} \rightarrow 14.20 \text{ MHz}$, too-long vertical dummy, so that it can be reused later without having to measure it again to remember what it simulates.

C. Measuring the DUT with the LiteVNA

1. Calibrate **CALIBRATE** for S11 with a span that covers at least 13–15 MHz and a high point density (see Exercise 1).
2. Connect the DUT **directly** to port 1 — avoid extra adapters/cables where possible, since they move the reference plane away from the components and introduce errors.
3. Set up two traces: **DISPLAY → FORMAT → RESISTANCE** and **DISPLAY → FORMAT → REACTANCE**, both on S11.
4. Place a marker at 14.20 MHz and read R and X in the status line.
5. Compare with the target values from part A ($R \approx 50\ \Omega$, $X \approx +250\ \Omega$). Small deviations are normal because of component tolerances and the SMA connector's own parasitic inductance.
6. Fine-trim if needed: adjust the number of turns on the inductor (changes L, and so X) or switch to the nearest standard resistor value (changes R), and measure again until the DUT hits the desired impedance accurately enough for the purpose.

D. Using the DUT in a matching exercise

1. Use this DUT directly as the test object in the procedure from Exercise 6, to design an L-network that transforms the impedance to a purely resistive $50\ \Omega$ at 14.20 MHz.
2. The advantage over a real antenna: the DUT is a fixed, known and weatherproof load — you can repeat the matching exercise identically as many times as you like, indoors.
3. Compare the matching network you find experimentally with the Smith chart, as a check on your own understanding of the transformation.

Tip: other antenna types

The same principle can be used to build dummy loads for other antennas/bands. If the desired reactance is capacitive instead (typical for an electrically too-short antenna, or e.g. a real $5/8\lambda$ vertical — see

Background above), replace the inductor with a series capacitor ($C = 1 / (2\pi f \cdot |X|)$). If you want

a purely resistive dummy load without reactance (e.g. for a resonant quarter-wave vertical, $R \approx 36\ \Omega$), a single non-inductive resistor is enough.

Pitfall: valid only at the design frequency

The DUT simulates the antenna's impedance correctly only in a narrow frequency window around the design frequency. A simple series circuit of R and L has a different frequency dependence from a real antenna's reactance, so do not use this DUT to study the shape of the SWR curve or bandwidth — only to practise point-impedance matching at one specific frequency.

Exercise 8 — Using measurement data in an external program: Smith chart and matching with an S1P file

Intermediate

Goal: Export the S11 measurement data from the DUT in Exercise 7 as an S1P file, import the file into the web-based tool <https://onlinesmithchart.com/>, design a matching network there, and see what the SWR becomes across the whole 20 m band with the matching section in place — and understand why such a match is only perfect at one particular frequency.

EQUIPMENT

- LiteVNA, calibrated for reflection (S11), with the DUT from Exercise 7 (or a real antenna/load you want to analyze yourself)
- MicroSD card (FAT/FAT32, < 32 GB)
- PC with a web browser and an internet connection
- A simple text editor (e.g. Notepad) for viewing the contents of the S1P file
- Web address: <https://onlinesmithchart.com/> (free web-based Smith chart tool)

Background: S1P and S2P files (Touchstone format)

The "Touchstone" format is an industry standard for storing measured or simulated S-parameters, and is the file format the LiteVNA uses when you save measurement data via the **SD CARD** menu (see Exercise 2).

- **.s1p**
— data for *one* port: only S11 (the reflection coefficient). Used for one-port devices such as an antenna, a load or the DUT in this exercise.
- **.s2p**
— data for *two* ports: S11, S21, S12 and S22. Used for two-port devices such as filters, cables or chokes (e.g. Exercise 9 and Exercise 10), where you are also interested in the transmission through the component.

The file is plain text: a comment line may start with **!**, one header line starts with **#** and describes the frequency unit, data format and reference impedance (e.g. **# MHz S RI R 50** — frequency in MHz, S-parameter data, RI = rectangular real/imaginary form, reference impedance 50 Ω), followed by one data line per measurement frequency. The format of the numbers can vary between RI (real/imaginary), MA (magnitude/angle) or dB (dB/angle), and the frequency unit can vary between Hz/kHz/MHz/GHz — the header line always determines which convention that particular file uses, so check this line before you interpret the numbers manually.

A. Measure and save the DUT's S11 as an S1P file

1. Set up and calibrate exactly as in Exercise 7 part C: S11, with a span that covers at least 13–15 MHz.
2. Connect the DUT from Exercise 7.

3. Go to the **SD CARD** menu and save the measurement data as an S1P file on the MicroSD card, e.g. with the file name **dut_exercise7.s1p**.
4. Insert the MicroSD card into the PC and copy the file across (alternatively: use "Export Data" in NanoVNA-App directly over USB, see the front matter).

B. Look at the contents of the file

1. Open the S1P file in Notepad (right-click the file → Open with → Notepad).
2. Find the header line (starts with **#**) and read which frequency unit, data format and reference impedance the file uses.
3. Note that each following line represents one measurement frequency, with two numbers for S11 (according to the format in the header line).

Example (illustration)

Below is a calculated example of what an S1P file for the DUT in Exercise 7 might look like, computed directly from the DUT's nominal component values ($R = 50\ \Omega$, $L \approx 2.80\ \mu\text{H}$) — *not* really measured data. Use it only to recognize the structure; in practice you should use your own file from part A.

```
# MHz S RI R 50
13.000 0.839700 0.366884
13.400 0.847691 0.359320
13.800 0.855132 0.351967
14.200 0.862069 0.344828
14.600 0.868543 0.337899
15.000 0.874593 0.331179
```

C. Import the S1P file into <https://onlinesmithchart.com/>

1. Open <https://onlinesmithchart.com/> in the browser.
2. Click the **S-Parameter** component at the top of the component list — this adds a separate S-parameter block to the circuit (labelled "DP1"), with a button **"ENTER S-PARAM FILE"**.
3. Click the button, and paste the entire raw text content of the S1P file (copied from Notepad) into the text box that appears ("Paste .s1p or .s2p file contents below").
4. Click **Save**. The tool interprets the file automatically and confirms the file type, frequency unit, data format and reference impedance — a useful double-check against what you read yourself in part B.
5. The Smith chart now shows the S11 curve of your DUT/antenna across the whole measured frequency range.

D. Design the matching network directly in the tool

1. Under "Settings & Features", set **Frequency** to the design frequency (14.20 MHz) and **Frequency Span** $\pm$ to e.g. 1 MHz, so that you can easily read off the point you are going to match.

2. Read the impedance at the design frequency in the result field ($Z = \dots$) — it should agree with what you measured on the LiteVNA in Exercise 7 part C ($R \approx 50 \Omega$, $X \approx +250 \Omega$).
3. Since R here is already $\approx 50 \Omega$, the L-network from Exercise 6 ($Q = \sqrt{(Z_{\text{high}}/Z_{\text{low}} - 1)}$) simplifies to $Q = 0$ — all that is needed is to cancel the reactance with a single series component, not a full two-component L-network.
4. Click **Series Capacitor** in the component list to insert a series capacitor in the chain between the source (50Ω) and your S-parameter block.
5. Adjust the capacitor value in the field that appears until the reflection coefficient/S11 at the design frequency is as small as possible — the Smith point then moves towards the centre, and the VSWR towards 1.00.

Required capacitance: $C = 1 / (2\pi f \cdot X) = 1 / (2\pi \cdot 14.2 \cdot 10^6 \cdot 250) \approx 44.8 \text{ pF}$

In practice you will often use the nearest standard value (e.g. 47 pF) or a small trimmer capacitor for fine adjustment, in the same way as in Exercise 6.

E. See what the SWR becomes across the whole 20 m band

1. Widen **Frequency** to the middle of the band (14.175 MHz) and **Frequency Span** $\pm$ to 0.175 MHz, so that the whole 20 m band (14.000–14.350 MHz) is displayed.
2. Read the VSWR curve in the graph over this range.

Frequency	Z after matching	VSWR
14.000 MHz	$50 - j7.1 \Omega$	1.15
14.100 MHz	$50 - j3.5 \Omega$	1.07
14.200 MHz (design)	$50 + j0.0 \Omega$	1.00
14.300 MHz	$50 + j3.5 \Omega$	1.07
14.350 MHz	$50 + j5.3 \Omega$	1.11

Pitfall: the match is perfect at one frequency only

Note that the VSWR is exactly 1.00 only at exactly 14.20 MHz — at the band edges it has already crept up towards 1.1–1.15. This is not a weakness of the tool or of this DUT in particular, but a fundamental property of *all* matching networks built from fixed components: an inductor and a capacitor change their reactance differently with frequency (X_L increases, X_C decreases), so the cancellation is exact at one point only. The steeper the impedance curve of the load, the narrower the frequency window in which the match is "good enough". This is also the reason why antennas with a wide operating range often need an antenna tuner (adjustable matching) instead of a fixed network.

At the same time, remember the pitfall from Exercise 7: this DUT (a simple R–L series circuit) does not have exactly the same frequency dependence as a real antenna, so the exact VSWR figures above should not be read as a claim about the bandwidth of a real antenna — but the principle itself ("perfect match only at the design frequency") is universal and applies just as much to a real antenna.

Tip: use your own data

This procedure works with any S1P file — feel free to try it with a real antenna you have available instead of the DUT. If you also have an S2P file (e.g. from Exercise 9 or Exercise 10), the same tool can be used to plot S21 and analyze two-port components in the same way.

Exercise 9 — Resonant frequency and Q of a trap (80 m/60 m)

Intermediate

Goal: Measure a stand-alone trap (a parallel LC circuit used in "trap" antennas) to determine its resonant frequency and Q, before it is mounted in the antenna.

EQUIPMENT

- LiteVNA, calibrated for transmission (S21) — see Exercise 1
- Method A: a simple test fixture: two short cables/adapters from port 1 and port 2 that meet at a point where the trap can be connected in series with the signal conductor, with the shield (ground) connected straight through
- Method B: two small coupling loops (about 2 turns, roughly the same diameter as the trap itself) connected to a cable/adaptor from port 1 and port 2 respectively, plus a simple holder made of wood (or another non-conductive material with little influence on the measurement) to hold the trap and loops at a fixed, loose distance from each other
- The trap(s) to be tested (e.g. for 80 m and 60 m)

Background

A trap is a parallel LC circuit. At its resonant frequency it has a very high impedance (almost an open circuit) and electrically "cuts off" the rest of the antenna, so that only the innermost part is active. Placed directly in series in a transmission measurement (S21, Method A), the trap will therefore give a clear attenuation (a "dip") in S21 precisely at the resonant frequency. If the trap is instead coupled inductively/loosely to both ports (Method B), it behaves as a loosely coupled band-pass filter and gives a clear

peak

in S21 at resonance instead.

Method A: Direct series test (trap loaded)

1. Build/connect the test fixture so that the trap can be connected in series directly into the signal path between port 1 and port 2, with a short and consistent ground connection.
2. Do a **thru calibration** (S21) with the test fixture *without* the trap inserted (or with a straight piece of wire instead), so that the rig's own loss and any leakage are nulled out. Preferably also do an OSL reflection calibration at the same time (see Exercise 1).
3. Set the frequency range wide enough to catch the expected resonance, e.g. 3.0–5.5 MHz to cover both an 80 m and a 60 m trap.
4. Set the number of measurement points high (`STIMULUS → CFG SWEEP`) for good resolution around the resonance dip itself.
5. Insert the trap in the test fixture (connected in series in the signal path, ground straight through).
6. Set `DISPLAY → CHANNEL → S21` and `DISPLAY → FORMAT → LOGMAG`, and find the frequency with the greatest attenuation — this is the trap's parallel resonant frequency f_0 .
7. Note the attenuation at the bottom of the dip (in dB).

8. Use markers to find the -3 dB points *relative to the bottom value of the dip* (not relative to 0 dB) on each side of the resonance: the lower frequency f_1 and the upper frequency f_2 .

9. Calculate Q with the formula: $Q = f_0 / (f_2 - f_1)$

10. **Shortcut:** instead of finding the -3 dB points and calculating Q manually (the two steps above), you can use **MEASURE → FILTER (S21)** in the main menu — the LiteVNA then automatically finds f_0 , the -3 dB/ -6 dB bandwidth and Q, and shows them directly on the screen.
11. Compare f_0 with the desired design frequency for the trap. If f_0 is too low: reduce the inductance/capacitance (fewer turns or a smaller capacitor). If f_0 is too high: increase the inductance/capacitance. Measure again after adjusting, and repeat for each trap that is to be used.

Method B: Loosely coupled measurement (trap unloaded)

We use essentially the same measurement principle as in Method A. The difference is that we connect a small loop (2 turns, with approximately the same diameter as the trap) to port 1 and port 2. We want a measurement setup in which the trap is not loaded, so that we can measure the trap's Q without significant loading from the measurement setup itself. The whole thing is suspended in a holder made of wood, which has little influence on the measurement.

1. Make the two coupling loops (about 2 turns each, roughly the same diameter as the trap) and connect them to a cable/adaptor from port 1 and port 2 respectively.
2. Mount the trap and the two coupling loops in the wooden holder so that they are held at a fixed, but *loose* distance from each other — no galvanic contact, only inductive coupling. The looser the coupling, the less the setup loads the trap's own Q, but the weaker the signal through also becomes.
3. Do a **thru calibration** (S21) with the loops in the setup but without the trap present (or with the trap far enough away that the coupling is negligible), so that the setup's own contribution is nulled out.
4. Set the frequency range and number of measurement points as in Method A.
5. Put the trap in place in the wooden holder between the loops.
6. Set **DISPLAY → CHANNEL → S21** and **DISPLAY → FORMAT → LOGMAG**. You will now see a clear **peak** in S21 at the trap's resonant frequency (the opposite of the dip in Method A), since the trap and loops now form a loosely coupled resonant-circuit filter.
7. Use the same menu choice as in Method A, **MEASURE → FILTER (S21)**, to let the LiteVNA automatically find the peak, the -3 dB/ -6 dB bandwidth and Q.
8. Compare the Q with the result from Method A — Method B normally gives a higher (more realistic) Q, since the trap is loaded less by the measurement setup itself.

Bonus

DISPLAY → TRANSFORM → BANDPASS (time domain) can show the trap's impulse response as a supplement — useful for seeing whether there are extra resonances from the test fixture.

Pitfall

The test fixture's own parasitic capacitance/inductance and cabling can shift the measured f_0 relative to how the trap behaves when mounted in the actual antenna. Use the shortest and most consistent set-up possible. In Method B: coupling that is too tight loads the trap (giving too low a Q and a shifted f_0 , as in Method A), while coupling that is too loose gives a weak signal and more noise in the reading — look for a sensible middle ground.

Exercise 10 — Characterizing a filter

Intermediate

Goal: Measure the insertion loss, cut-off frequency(ies), stop-band attenuation and any ripple of a low-pass, high-pass or band-pass filter.

EQUIPMENT

- LiteVNA, calibrated for transmission (S21) and reflection (S11)
- The filter to be tested

1. Calibrate thru (S21) and OSL (S11) over a wide frequency range that covers both the pass band and the stop band well beyond the filter's expected cut-off frequencies (see Exercise 1).
2. Insert the filter in the signal path between port 1 and port 2.
3. Show `DISPLAY → CHANNEL → S21`, `FORMAT → LOGMAG` on one trace, and S11 (`SMITH` or `LOGMAG`) on another.
4. Identify the pass band (low loss, typically near 0 dB) and the stop band (high loss).
5. Use a marker to find the -3 dB cut-off frequency(ies) — where S21 has fallen 3 dB from the pass-band level.
6. For band-pass/band-stop filters: find both the upper and lower cut-off frequencies, and calculate the bandwidth and, if relevant, Q as in Exercise 9.
7. **Shortcut:** instead of doing the steps above manually, you can use `MEASURE → FILTER (S21)` in the main menu. The LiteVNA then recognizes by itself whether the filter is low-pass, high-pass, band-pass or band-stop, and automatically calculates Q, the -3 dB and -6 dB points (with the associated frequencies), and the loss in the pass band and stop band.
8. Note the attenuation in the stop band at specific frequencies of interest (e.g. harmonics or neighbouring bands that are to be suppressed).
9. Check the return loss (S11) in the pass band — a high return loss (low S11) indicates a good match; heavy ripple can indicate incorrect termination or damage in the filter.
10. Compare the results with the data sheet specification if available.

Bonus

`DISPLAY → TRANSFORM → BANDPASS` (time domain, format LINEAR/LOGMAG/SWR) simulates the filter's response to an impulse signal and can give a quick visual impression of group delay/ringing in the filter.

Tip

Many compact filters are sensitive to source impedance. Use short, well-matched cables between the LiteVNA and the filter to avoid extra ripple in the measurement that is not caused by the filter itself.

Exercise 11 — Measuring an L/C component and its self-resonance

Intermediate

Goal: Determine the actual inductance or capacitance of a component, and find its self-resonant frequency (SRF) — important knowledge before the component is used at HF/VHF.

EQUIPMENT

- LiteVNA, calibrated for reflection (S11)
- The component to be tested (inductor or capacitor)
- A simple test fixture with a short, consistent set-up

1. Calibrate the LiteVNA for reflection with the reference plane as close to the component's connection point as possible.
2. Connect the component as a shunt to ground on port 1 (or in series in a two-port set-up with S21, as in Exercise 9).
3. Set a frequency range that covers the expected operating frequency, but does not yet go all the way up towards the expected self-resonance.
4. Set `DISPLAY → FORMAT → REACTANCE` to read the reactance X directly in ohms — preferably show an extra trace with `FORMAT → RESISTANCE` for the loss component R.
5. Place the marker at a frequency well below the expected SRF, where the component still behaves "purely" inductively/capacitively (the phase angle of Z should lie close to $\pm 90^\circ$, see the shortcut below), and read X in the status line for the active trace.

6. Calculate the component value:

◦ Inductor: $L = X / (2\pi f)$

◦ Capacitor: $C = 1 / (2\pi f \cdot |X|)$

7. **Shortcut:** instead of calculating L/C manually from X, you can let the LiteVNA do it directly. Set `DISPLAY → FORMAT → SMITH`, then press the trace format once more to bring up further presentation choices, and select `R+L/C` — the marker value is then shown directly in μH or pF, already calculated. Read the value at a frequency where the phase reading (preferably show `Z PHASE` as an extra trace) lies close to $\pm 90^\circ$: that is precisely the criterion for the component still behaving "purely" reactively (the loss resistance R is negligible compared with X); closer to the SRF the phase will move away from 90° and the L/C reading becomes less reliable.
8. Extend the frequency range upwards and move the marker towards where the REACTANCE curve crosses zero (changes sign from inductive to capacitive for an inductor, or the reverse for a capacitor) — this is the component's self-resonant frequency (SRF). **Tip:** preferably use `Z PHASE` as a trace instead of/in addition to REACTANCE — the phase changes sign (from about $+90^\circ$ to about -90° , or the reverse) exactly at the SRF, the same information as the zero crossing in X, but the sign change is often easier to spot clearly because the phase scale always spans $\pm 180^\circ$ no matter how small $|X|$ is right there.

9. Judge whether the component is suitable for the intended operating frequency; it should normally lie well below the SRF for predictable behaviour.

Tip

RF chokes with many turns can have a surprisingly low SRF because of winding capacitance — this is especially important to check for chokes and choke coils used at HF/VHF.

Pitfall

The test fixture's own parasitic inductance/capacitance affects the measurement. Keep the leads to the component as short as possible, and calibrate as close to the component as possible.

Exercise 12 — Measuring a balun/common-mode choke

Intermediate

Goal: Measure the common-mode impedance of a balun or choke over frequency, to confirm that it attenuates feed-line currents sufficiently in the band in question.

EQUIPMENT

- LiteVNA, calibrated for transmission (S21)
- The balun/choke to be tested
- A test fixture in which both conductors are shorted together at each end, to force common-mode current through the core

1. Build the test fixture so that the winding that is to act as a common-mode choke is connected in series in the signal path between port 1 and port 2, with both conductors (inner conductor and shield, or the two winding ends) shorted together at each end.
2. Do a thru calibration with the fixture without the choke inserted (use a straight short instead), so that the fixture's own contribution is nulled out.
3. Insert the choke/balun into the fixture.

4. Set `DISPLAY → CHANNEL → S21`, `FORMAT → LOGMAG`, and measure S21 in dB over the desired frequency range.

5. Calculate the common-mode impedance with the same formula used for a series resistor measured via

insertion loss in a 50 Ω system (see also Exercise 16): $Z = 2 \cdot 50 \, \Omega \cdot (10^{(-S21_{dB}/20)} - 1)$ (Use

a negative S21_{dB} so that the exponent becomes positive, since S21 is normally measured as a negative value.)

6. Compare the common-mode impedance with the recommended minimum value for the purpose (rule of thumb: ≥ 500 Ω in the HF band for an effective balun/choke).
7. Repeat for several core types/numbers of turns if you are comparing alternatives, and note which combination gives the best impedance in the desired band.

Tip

This test measures only the common-mode property (choking impedance), not the balun's ability to transform impedance in differential mode — these are two separate properties that should be assessed separately.

Pitfall

Make sure the shorts in the fixture are short and solid. Loose connections give extra loss/resonances in the measurement that are not caused by the choke itself.

Exercise 13 — Cable length by phase measurement

Intermediate

Goal: Determine the physical length of a cable by measuring how the reflection phase (S11 PHASE) changes with frequency — a simpler, TDR-independent method that uses an ordinary frequency-domain measurement instead of the IFFT-based time domain (see Exercise 14 for the TDR method and a cross-check between the two).

EQUIPMENT

- LiteVNA, calibrated for reflection (S11)
- The cable to be measured, with a known velocity factor (VF)
- An open or a short at the end of the cable (both work equally well for this method)

Background

The reflection coefficient at the cable input is:

$$\Gamma_{in}(f) = \Gamma_{load} \cdot e^{-j \cdot 2\beta \cdot L}, \quad \beta = 2\pi f / (c \cdot VF)$$

The phase of Γ_{in} decreases linearly with the frequency f . If the phase goes from -90° to $+90^\circ$ (through the wrap point at $\pm 180^\circ$ on an ordinary phase scale) it has rotated exactly 180° — this corresponds to the cable's *one-way* electrical length having changed by exactly a quarter wavelength ($\lambda/4$) over that frequency span. Solving for the length:

$$L = c \cdot VF / (4 \cdot \Delta f)$$

where Δf is the frequency distance between the point where the phase is -90° and the point where it is $+90^\circ$, and $c = 299,792,458$ m/s. The advantage of precisely these two points is that they are easy to read visually (the quarter-scale marks on a $\pm 180^\circ$ phase scale), and that only the *difference* Δf counts — the absolute phase reference from the calibration does not matter.

1. Calibrate **CALIBRATE** for S11.
2. Connect the cable to port 1, and leave the far end open or shorted (note which — it does not affect the calculation, but is good to know for interpretation).
3. Set **DISPLAY → FORMAT → PHASE** on S11.
4. Set a wide frequency range and look at the phase line — it should fall steadily with increasing frequency and "wrap" (jump from -180° to $+180^\circ$) at regular intervals. Narrow the span around *one* continuous fall from -90° to $+90^\circ$ (through the nearest wrap point).
5. Place marker 1 exactly where the phase is -90° , and note the frequency f_1 .

6. Place marker 2 where the phase (after the wrap) reaches $+90^\circ$, and note the frequency f_2 .

7. Calculate $\Delta f = f_2 - f_1$ and then the cable length: $L = c \cdot VF / (4 \cdot \Delta f)$

8. Compare with the physically measured length, or cross-check against the result from the TDR method in Exercise 14.

Example: an RG58 cable ($VF = 0.66$) with a physical length of 20 m should give:

$$\Delta f = c \cdot VF / (4 \cdot L) = 299,792,458 \cdot 0.66 / (4 \cdot 20) \approx 2.47 \text{ MHz}$$

Pitfall

Make sure marker 1 and marker 2 are *adjacent* crossing points (only one wrap point between them), not two points further apart in the sweep. If you skip an extra full or half rotation by mistake, Δf will be wrong and L will be calculated too short. This method is also easier to use on short to medium-length cables, where it is easy to follow the phase visually through just one rotation — for very long cables (many fast wrap cycles) the TDR method in Exercise 14 is more robust.

Exercise 14 — Cable length and velocity factor (built-in TDR)

Advanced

Goal: Use the LiteVNA's built-in time-domain function (TDR/DTF, computed with an IFFT directly on the device) to determine the physical length and velocity factor (VF) of a cable, or to find the distance to a break/damage — entirely without PC software. (See Exercise 13 for a simpler, phase-based method without TDR — useful as a quick cross-check.)

EQUIPMENT

- LiteVNA, calibrated for reflection (S11)
- The cable to be tested (known or unknown length/VF)

1. Calibrate **CALIBRATE** for S11. Set **STIMULUS → START** to exactly **50 kHz** (required by the firmware for low-pass TDR) and **STOP** according to the desired measurement distance — the lower the stop frequency/the denser the point spacing, the greater the maximum distance; the higher the stop frequency, the better the spatial resolution.
2. Set the highest possible number of points (**STIMULUS → CFG SWEEP**, up to 1001) for the best resolution.
3. Connect the test cable to port 1 and leave the far end open (often gives a clear peak) or shorted.
4. Open **DISPLAY → TRANSFORM → TRANSFORM ON**.
5. Select **LOW PASS IMPULSE** (shows the reflection as a clear pulse) or **LOW PASS STEP**.
6. Set the trace format to **REAL** (**DISPLAY → FORMAT → REAL**) — this is the format low-pass mode is to be displayed in.
7. Set the velocity factor under **DISPLAY → TRANSFORM → VELOCITY FACTOR**. Enter the number as an integer *without* a decimal point (e.g. **67** for VF = 0.67).
8. If the cable's physical length is **known**: adjust VELOCITY FACTOR until the marker on the reflection peak shows the correct distance (the distance is shown together with the time value in the marker readout). Note this VF value for later use with the same cable type.
9. If the VF is **known** (from the data sheet) and you are instead looking for the length or a fault: read the distance directly at the marker on the reflection peak — this is the distance to the end of the cable, or to any fault (break, short, moisture damage) if it lies closer than the cable's physical end.
10. Use **WINDOW** (MINIMUM/NORMAL/MAXIMUM) to trade resolution against noise: MINIMUM gives the sharpest peak and highest resolution, MAXIMUM suppresses noise/ringing best but gives a wider peak.
11. Interpretation: a sharp, clear peak means an abrupt discontinuity (open/short/break). A gradual change in the baseline before the expected end point can indicate moisture or gradual damage in the cable. A capacitive/inductive discontinuity along the way (e.g. a poor splice) shows up as a small dip/peak in the middle of the line.

Calculation: stop frequency for the desired measurement distance

The LiteVNA computes the time domain from the frequency sweep with an inverse FFT (IFFT). The frequency step between the measurement points, Δf , determines how large the unambiguous time window (and thus the

maximum distance) is:

$$\Delta f = F_{\text{stop}} / (N - 1)$$

($F_{\text{start}} = 50$ kHz is negligible compared with F_{stop} , so the span $\approx F_{\text{stop}}$)

The unambiguous time window is $T = 1/\Delta f$. The reflection travels there and back in the cable (round trip), so the maximum unambiguous measurement distance D_{max} (the distance to the end of the cable or to a fault) becomes:

$$D_{\text{max}} = c \cdot VF \cdot (N - 1) / (2 \cdot F_{\text{stop}})$$

Solving for the stop frequency — for a desired measurement distance D_{max} , number of points N ([STIMULUS → CFG SWEEP](#)) and velocity factor VF — gives:

$$F_{\text{stop}} = c \cdot VF \cdot (N - 1) / (2 \cdot D_{\text{max}})$$

where $c = 299,792,458$ m/s. **Example:** you want to measure an RG58 cable ($VF = 0.66$) up to 50 m, with $N = 1001$ points (the LiteVNA's maximum):

$$F_{\text{stop}} = 299,792,458 \cdot 0.66 \cdot 1000 / (2 \cdot 50) \approx 1.98 \text{ GHz}$$

Note that the spatial resolution (the smallest distance between two reflectors that you can tell apart) is determined by the whole frequency span alone ($\approx F_{\text{stop}}$), *not* by the number of points:

$$\Delta D = c \cdot VF / (2 \cdot F_{\text{stop}})$$

The number of points N thus only decides how many resolution cells fit within D_{max} ($D_{\text{max}}/\Delta D = N - 1$): more points do not give better resolution by themselves, but let you keep good resolution together with long range — without more points, F_{stop} must be lowered to reach far, and the resolution gets worse at the same time.

Valid measurement values

According to the specification table in the official LiteVNA user manual, these limits apply to N and F_{stop} in the formulas above:

- **Number of points N :** 21–1001, adjustable on the device itself ([STIMULUS → CFG SWEEP](#)). Over USB/PC software up to 65,535 points can be set, but it is the device's own sweep (max 1001) that the built-in TDR transform uses.
- **Frequency range:** 50 kHz – 6.3 GHz. F_{start} is fixed at 50 kHz in low-pass TDR (step 1), and F_{stop} cannot be set higher than 6.3 GHz.

This sets a practical upper limit on how well the LiteVNA can do TDR: with the maximum number of points ($N=1001$) and the maximum stop frequency ($F_{\text{stop}}=6.3 \text{ GHz}$), the best achievable resolution for a $VF=0.66$ cable is

$$\Delta D_{\text{min}} = c \cdot 0.66 / (2 \cdot 6.3 \cdot 10^9) \approx 1.6 \text{ cm}$$

but then the maximum unambiguous measurement distance is at the same time limited to

$$D_{\text{max}} = c \cdot 0.66 \cdot 1000 / (2 \cdot 6.3 \cdot 10^9) \approx 15.7 \text{ m}$$

If you are going to measure cables longer than this, F_{stop} must be lowered correspondingly (see the formula above), at the expense of resolution.

Bonus: reading the impedance of each cable segment at splices

If you splice together several cable types with different characteristic impedances (e.g. three segments with three different Z), TDR can in principle show the impedance of each segment — but the LiteVNA does *not* display ohms directly in the time domain. The **REAL** format used in low-pass mode (see step 6) shows the real part of the reflection coefficient Γ (a value between -1 and $+1$) at each point, and you have to convert to impedance yourself.

1. Use **LOW PASS STEP** (not **IMPULSE**) — the step response shows a flat plateau for each cable segment, with a transition at each splice. **IMPULSE** only shows a peak/trough at the transitions and is less suited to reading absolute levels.
2. Read the plateau level (Γ) with a marker in the middle of each flat plateau — *not* in the transition itself between the plateaus.
3. The first segment (cable 1) is normally a 50Ω cable matched to the port, so the plateau before the first splice lies at $\Gamma \approx 0$. The reflection coefficient at the first splice, Γ_1 , is then simply the plateau level *after* the

first transition, ρ_1 :

$$\Gamma_1 = \rho_1 \quad Z_2 = Z_1 \cdot (1 + \Gamma_1) / (1 - \Gamma_1)$$

4. For splice no. 2 (and later) you can **not** use the plateau level ρ_2 directly as Γ_2 — the signal has already lost some amplitude in transmission through the first splice (and again on the way back). The correct local

reflection coefficient at splice 2 is:

$$\Gamma_2 = (\rho_2 - \rho_1) / (1 - \rho_1^2)$$

$$Z_3 = Z_2 \cdot (1 + \Gamma_2) / (1 - \Gamma_2)$$

5. Repeat the same pattern (use the previous segment's calculated impedance as the new reference Z_{n-1}) for any further splices further out along the cable.

Caveat

This is a first-order ("single-bounce") approximation that ignores multiple internal reflections between the splices ("ghost" reflections). It is accurate enough when the mismatches are moderate and the cable has some attenuation that dampens the secondary reflections — typically this holds well enough for ordinary amateur radio coaxial cables. Professional TDR equipment uses a deconvolution algorithm for full accuracy with many/large impedance steps; neither the LiteVNA nor this simple hand calculation has that. The segments must also be long enough for the plateaus to flatten out between the splices (see spatial resolution ΔD above) — with segments that are too short the transitions merge and cannot be told apart.

Tip

This technique is useful for verifying the length of ready-made feed lines, uncovering hidden splices, or locating a break in a buried/concealed cable without having to dig it up. You can also use NanoVNA-App or NanoVNA-Saver on a PC for a larger display and built-in VF presets for common cable types, but the TDR calculation itself always happens in the LiteVNA.

Pitfall

The START frequency must be exactly 50 kHz in low-pass mode for the IFFT calculation to be correct. Remember that maximum measurement distance and resolution are in a trade-off relationship — use a lower frequency for longer distance, a higher frequency for finer resolution at short distances.

Exercise 15 — Fault finding and distance measurement with TDR

Advanced

Goal: Use the LiteVNA's built-in TDR (as in Exercise 14) to identify the type of fault/discontinuity in a cable — short circuit, break, wrong impedance, or a reactive component (inductor/capacitor) — from the shape and sign of the reflection, and to locate a branch (T-junction) in a cable.

EQUIPMENT

- LiteVNA, calibrated for reflection (S11)
- A length of coaxial cable with a known velocity factor (VF), connected to port 1
- A simple interchangeable end adapter/test fixture (as in Exercise 11) for testing different terminations at the end of the cable: short, open, a resistor $> 50 \Omega$ (e.g. 150Ω), a resistor $< 50 \Omega$ (e.g. $18\text{--}22 \Omega$), a capacitor (e.g. $100\text{--}470 \text{ pF}$) and an inductor (e.g. $1\text{--}4.7 \mu\text{H}$)
- A T-adapter (BNC/SMA) and a short extra piece of cable, for part D (locating a branch)
- Tape measure/folding rule to verify physical distances against the TDR reading

A. Calculate the stop frequency for the desired measurement distance and resolution

As derived in Exercise 14:

$$F_{\text{stop}} = c \cdot \text{VF} \cdot (N - 1) / (2 \cdot D_{\text{max}})$$

where $c = 299,792,458 \text{ m/s}$, N is the number of measurement points and D_{max} the desired maximum measurement distance in metres. The table below gives the constant $c \cdot (N-1)/2$ (in $\text{MHz} \cdot \text{m}$) for the LiteVNA's most common point counts, so that $F_{\text{stop}}(\text{MHz}) = \text{constant} \cdot \text{VF} / D_{\text{max}}(\text{m})$:

Number of points (N)	Formula for F_{stop} (MHz)
101 points	$14,990 \cdot \text{VF} / D_{\text{max}}$
201 points	$29,979 \cdot \text{VF} / D_{\text{max}}$
401 points	$59,958 \cdot \text{VF} / D_{\text{max}}$
1001 points (LiteVNA max)	$149,896 \cdot \text{VF} / D_{\text{max}}$

Remember that the resolution $\Delta D = c \cdot \text{VF} / (2 \cdot F_{\text{stop}})$ depends only on F_{stop} (not N) — more points do not give finer resolution by themselves, but let you reach further without having to lower F_{stop} (see Exercise 14 for the full derivation and "Valid measurement values").

B. Set up the measurement

1. Calibrate **CALIBRATE** for S11. Set **STIMULUS → START** to exactly 50 kHz and **STOP** according to the table in part A, based on the desired D_{max} and the cable's VF.

2. Set the number of measurement points (`STIMULUS → CFG SWEEP`) in line with your choice in part A.
3. Connect the main cable to port 1, with the end adapter/test fixture ready at the other end for quick changes of termination.
4. Open `DISPLAY → TRANSFORM → TRANSFORM ON` , select `LOW PASS STEP` (clearest for reading the level/direction of each termination), trace format `REAL` , and set `VELOCITY FACTOR` .
5. Measure the cable's physical length with the tape measure/folding rule — use this as the answer key to compare the marker reading against.

C. Test and interpret the reflection signatures at the cable end

Change the termination at the end of the cable and observe how the `LOW PASS STEP` curve behaves at the reflection point:

Termination	Level in LOW PASS STEP	Appearance
Open ($\infty \Omega$)	+1	Jumps instantly to, and stays at, the top
Short (0Ω)	-1	Jumps instantly to, and stays at, the bottom
Resistor $R > 50 \Omega$	between 0 and +1	Smaller positive jump than open, flat level (no time-varying shape)
Resistor $R < 50 \Omega$	between 0 and -1	Smaller negative jump than short, flat level
Resistor $R = 50 \Omega$	0	Invisible — matched, no reflection to see
Capacitor (C)	starts at -1, rises towards +1	Jumps instantly down to the bottom, then recovers <i>gradually</i> upwards (the capacitor "charges up" — eventually looks like an open at low frequency/long time)
Inductor (L)	starts at +1, falls towards -1	Jumps instantly to the top, then falls <i>gradually</i> downwards (the inductor "builds up current" — eventually looks like a short at low frequency/long time)

In `LOW PASS IMPULSE` the same thing is shown as a spike instead of a level step: open/short/R give a single spike (positive and negative respectively), while L and C give a **two-sided** spike — a sharp spike in one direction immediately followed by a wider, weaker spike in the opposite direction (positive-then-negative for an inductor, negative-then-positive for a capacitor). This two-sided pattern is the signature that distinguishes a reactive (frequency-dependent) fault from a simple resistive fault or a pure break/short.

Use the marker to read the distance to the reflection for each termination, and compare with the cable's physical length from part B.

Pitfall

These signs and shapes apply when the component sits
at the end

of the cable (a pure 1-port test, as here and in Exercise 11) — *not* necessarily for a component inserted in the middle of a line that continues onwards (see part D below). Also make sure the end adapter/test fixture has a short, consistent set-up; its own parasitic inductance/capacitance can shift the signature, especially for the R and C tests.

D. Locate a branch (T-junction) in the cable

Connect the T-adapter in the middle of the cable, with the short piece of cable continuing on one branch (terminate this stub open or shorted as a known, fixed reference). Leave the third connection on the T-piece open.

Background

A T-piece is a 3-way junction. Seen from port 1, the impedance you see into the T is the *parallel* combination of the stub cable's own impedance ($50\ \Omega$, since the reflection from its end has not yet had time to come back) and whatever is connected to the third connection. A parallel combination can never be higher than the lower of the two values — so the T-point itself can *never* give a positive reflection when the stub is $50\ \Omega$ matched, only zero (invisible, if the third port is open) to negative (towards -1 , if the third port is shorted). This is also why simple resistive T-splitters are never perfectly matched at all three ports at the same time — a useful practical lesson for using splitters in antenna installations.

1. With the third port open: look for the T-point in the TDR curve. It will often be almost invisible (close to 0), since an open third port does not load the junction noticeably.
2. Short the third port: the T-point will now show a clear negative reflection, since the junction is now pulled towards $0\ \Omega$.
3. Whatever the third port is set to: look for a *second*, fixed reflection further out — this is the end of the short cable stub (open or shorted, as set up at the start). Use a marker to read the distance to both points, and compare with physically measured lengths.

Bonus

If you need to find the impedance of several splices/segments one after another in a spliced cable (not a branch, but several cable types in series), see the Bonus section in Exercise 14 for the procedure and formulas ($\Gamma_n = (\rho_n - \rho_{n-1})/(1 - \rho_{n-1}^2)$, $Z_n = Z_{n-1} \cdot (1 + \Gamma_n)/(1 - \Gamma_n)$).

Exercise 16 — Measuring crystal parameters (R_m , L_m , C_m , Q)

Advanced

Goal: Determine a quartz crystal's electrical equivalent circuit — motional resistance (R_m), inductance (L_m), capacitance (C_m) and holder capacitance (C_0) — as well as the series/parallel resonant frequency and Q . Useful when building crystal filters or verifying crystals before use in oscillators.

EQUIPMENT

- LiteVNA, calibrated for reflection (S11) and transmission (S21)
- A simple two-port test fixture in which the crystal is connected in series in the signal path between port 1 and port 2 (as in Exercise 9/12)
- The crystal(s) to be measured

Background

A crystal is modelled electrically as a "motional" branch (R_m in series with L_m and C_m) in parallel with the holder capacitance C_0 . L_m/C_m determine the series frequency f_s (lowest loss, highest transmission). Slightly higher up a parallel resonance f_p occurs, where L_m/C_m in combination with C_0 gives a very high impedance (deep attenuation in S21). Crystals typically have an extremely high Q (many thousands).

A. Measuring C_0 (holder capacitance)

1. Connect the crystal directly to port 1 as a shunt to ground (S11) — not in the series test fixture yet.
2. Set the frequency range well below the crystal's specified frequency (e.g. a tenth of a decade lower), so that the motional properties do not affect the measurement.
3. Set `DISPLAY → FORMAT → REACTANCE`, and read X at a low frequency f .
4. Calculate $C_0 = 1 / (2\pi f \cdot |X|)$ (same procedure as in Exercise 11).

B. Finding the series and parallel resonance (f_s and f_p)

1. Build the test fixture so that the crystal sits in series in the signal path between port 1 and port 2, as in Exercise 9.
2. Do a thru calibration (S21) with the fixture without the crystal (a straight piece of wire instead).
3. Set a frequency window around the crystal's specified frequency, typically a 50–150 kHz span, with the highest possible number of measurement points (`STIMULUS → CFG SWEEP`).
4. Insert the crystal into the fixture.
5. Show two traces on channel S21: one with `FORMAT → LOGMAG` and one with `FORMAT → PHASE`.
6. f_s (series resonance) is the frequency with a clear **peak** in S21 (lowest loss), where the phase crosses 0° .

- f_p (parallel resonance) is a slightly higher frequency with a clear **dip** in S_{21} (high loss). Zoom in (narrower span) around each point if needed for better resolution.
- Note f_s and f_p accurately with a marker.

C. Measuring R_m (motional resistance) at f_s

- Reduce the span to a narrow window around f_s (typically 5–10 kHz).
- Read S_{21} in dB exactly at f_s (where the phase is 0°) — call the value S_{21_s} .
- Calculate: $R_m = 2 \cdot R_L \cdot (10^{(-S_{21_s}/20)} - 1)$ where $R_L = 50 \Omega$ (use a negative S_{21_s} so that the exponent becomes positive, since S_{21_s} is normally negative, e.g. -0.6 dB).

D. Calculating C_m and L_m — two methods for cross-checking

D1. The series/parallel method (from the wide sweep in part B):

$$C_m = (f_p/f_s - 1) \cdot 2 \cdot (C_0 + C_{\text{stray}})$$

$$L_m = 1 / ((2\pi \cdot f_s)^2 \cdot C_m)$$

(C_{stray} is the test fixture's own parasitic capacitance — set to 0 as a first approximation, or measure separately with an empty fixture.)

D2. The phase-shift method (finer, from the narrow span around f_s in part C):

- Find the frequency f_L where the phase is $+45^\circ$ and f_H where the phase is -45° (f_s is where the phase is 0°).

- Calculate: $R_{\text{eff}} = 2 \cdot R_L + R_m$ and $\Delta f = f_H - f_L$

- $C_m = \Delta f / (2\pi \cdot f_s^2 \cdot R_{\text{eff}})$

- $L_m = R_{\text{eff}} / (2\pi \cdot \Delta f)$

E. Calculating Q

Use the same Δf as in D2 (the $\pm 45^\circ$ points), or find the -3 dB points in S_{21} relative to the peak (as in Exercise 9):

$$Q_{\text{loaded}} = f_s / \Delta f$$

Important: since Δf is derived from $R_{\text{eff}} = 2 \cdot R_L + R_m$ (i.e. it includes the $100\ \Omega$ from the two ports in the measurement set-up), this is the *loaded* Q of precisely this $50\ \Omega$ test set-up — not the crystal's own, intrinsic Q. The crystal's **unloaded** Q (what is normally meant when quoting "the crystal's Q", e.g. in filter/oscillator design) uses only R_m from part C:

$$Q_{\text{unloaded}} = 2\pi \cdot f_s \cdot L_m / R_m$$

Since R_m is normally much smaller than R_{eff} (R_m is typically a few to a few tens of ohms, against $R_{\text{eff}} \approx 100 + \Omega$), Q_{unloaded} is usually 10–20× higher than Q_{loaded} — both figures are "correct", they just describe two different things.

Quantity	Typical value (example, HC-49 ~18.7 MHz)
C_0	$\approx 3.7\text{--}3.8\ \text{pF}$
R_m	$\approx 7\ \Omega$
C_m	$\approx 14.5\text{--}15.3\ \text{fF}$
L_m	$\approx 4.7\text{--}5.0\ \text{mH}$
Q_{loaded}	≈ 5000
Q_{unloaded}	$\approx 80,000$

Tip

Compare the results from D1 and D2 — they should agree reasonably well (the example table above shows the typical spread between the methods). Large deviations indicate an inaccurately read f_s/f_p , too low a point density, or too large a C_{stray} . There is also a third method (the "G3UUR method") that uses an external switched oscillator circuit and a frequency counter instead of a VNA — useful if you have such equipment available, but it does not require the LiteVNA at all for the calculation itself.

Pitfall

Crystals have an extremely high Q — use the narrowest possible span and the highest possible number of points around f_s for a reliable reading of phase and amplitude. The test fixture's own parasitic capacitance/inductance can shift C_0 and C_m significantly; keep the set-up short and as consistent as possible between calibration and measurement.

Prepared as course material for practical LiteVNA training (Dislord/LiteVNA firmware). Complete course, Exercise 1–16.

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