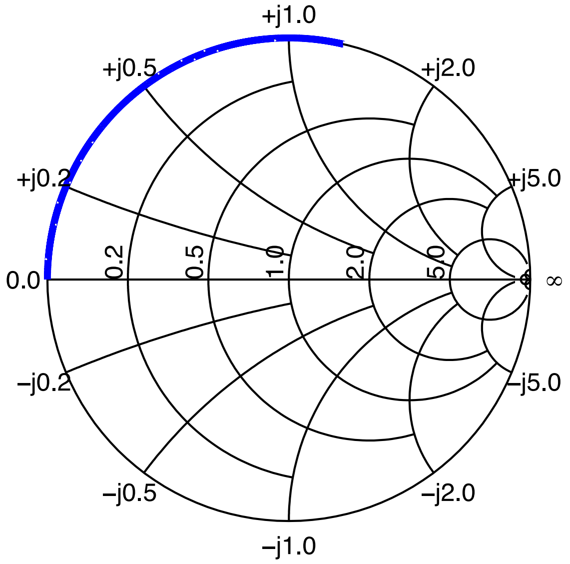
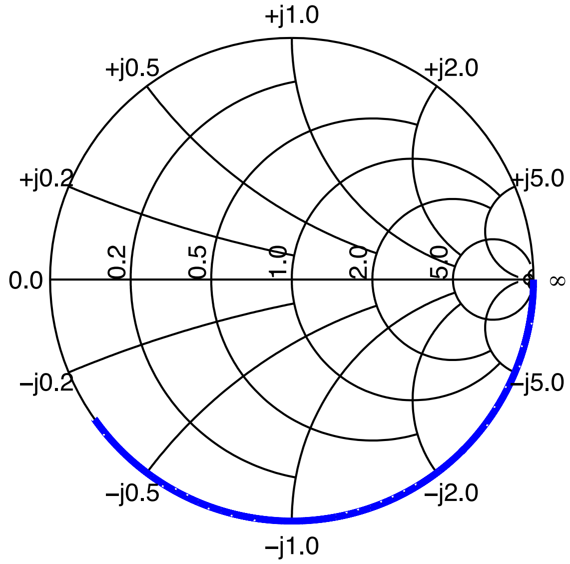
PRELIMINARY EXERCISE

Before starting the measurements, do what is indicated below and then verify the conclusions with the professor.

On Smith chart, the measure of a lumped element has the plot reported here, in the case of pure inductors (left graph, 1mH) or pure capacitors (right graph, 1uF).





Using the supplied Smith chart, draw the locus of points representing:

1) R-L series

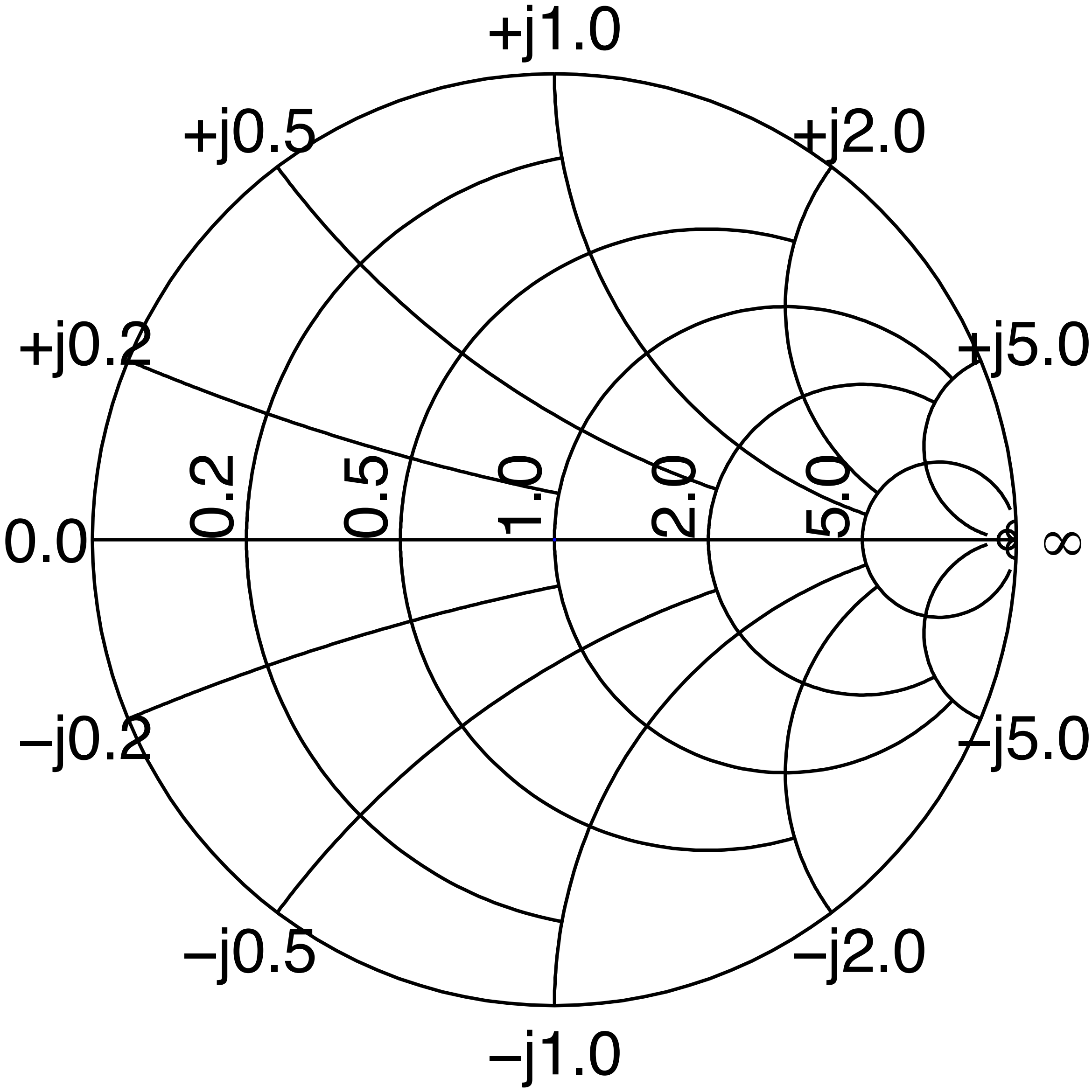
2) R-C series

3) R-L-C series

4) R-L parallel

5) R-C parallel

6) R-L-C parallel


+j1.0
+j0.5
+j2.0
+j0.2
+j5.0
0.0
0.2
0.5
1.0
2.0
5.0
∞
−j0.2
−j5.0
−j0.5
−j2.0
−j1.0

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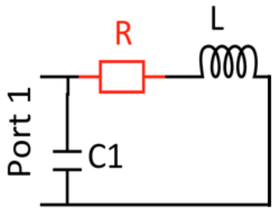
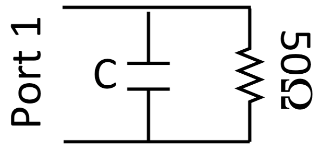
PRACTICE 03 – MEASUREMENTS ON LUMPED ELEMENTS

Circuital model of resistors connected to measuring devices



(a)

Circuital model of the T-juncion with C used below



(b)

Premise: calibrate **1601 points**, from 300kHz to 1.5GHz in **S11-1port** (reflection measurement) and save the state. Repeat in the 300kHz to 300MHz span, saving another state. In the ElectronicsLaboratory1 directory prepare a group directory when saving for the first time.

Calibrate **1601 points** from 300kHz to 300MHz **Response-1->2** (transmission measurement) and save the state in another file.

1. REFLECTION MEASUREMENTS ON A 6 Ω RESISTOR

On the desk, there is a resistor of 6Ω soldered on a type-N connector. The circuital model of the component is reported in Fig. a.

Use the 300kHz-1.5GHz span. Connect the resistor to the VNA port 1. Use the equation Math->Analysis->Conversion-> **Z-Reflection**

$$Z_{in} = 50 (1 + S11)/(1-S11) \quad (1)$$

1.1 Plot Real(Zin): estimate the value of R (through a linear fit) with uncertainty and read the value of Real(Zin) at resonance. How are those values linked? **(REPORT)**

1.2 Plot Im(Zin): estimate the value of L (through a linear fit) with uncertainty, the resonance frequency, C and the Q factor of the resonant circuit. **(REPORT)**

1.3 Save data and compare Real(Zin), Im(Zin) obtained and the results of Eq.1 applied to S11 measured (two plots versus frequency). **(REPORT)**

1.4 Save data, compare the measured |S11| and the Smith Chart with the expectation applying the circuital model with R,L, C measured in 1.1 and 1.2. **(REPORT)**

1.5 Use the Smith chart and markers to measure all the main points of the device behavior. **(VERIFY WITH THE PROFESSORS)**

1.6 Give a final estimate of R, L, C1 with uncertainty **(REPORT)**.

2. TRANSMISSION MEASUREMENTS ON A SHUNT 6 Ω RESISTOR

Use the 300kHz-1.5GHz span.

To get the shunt 6Ω resistor, use the T-junction (write the circuit model).

When using Math->Analysis->Conversion-> **Z-Transmit** the conversion is

$$Zs = 50 \cdot 2\,(1 - S21)/(S21) \quad (2)$$

When using Math->Analysis->Conversion-> **Z-Trans-Shunt** the conversion is

$$Zt = 50/2\; S21/(1-S21) \quad (3)$$

2.0 Verify the calibration of S21 measuring the “direct connection” used in the RESPONSE calibration. If it is not satisfying, repeat just the calibration of S21 (**Response 1->2**) and re-save. Report the measurement of the connection after calibrating. **(REPORT)**

2.1 Measure and save S21, Real(Zs) and Imag(Zs). Compare graphically Real(Zs) and Imag(Zs) with the results of Eq.2 starting from the measured S21. **(REPORT)**

2.2 Measure and save S21, Real(Zt) and Imag(Zt). Compare graphically Real(Zt) and Imag(Zt) with the results of Eq.3 starting from the measured S21. **(REPORT)**

2.3 Make an analytical estimation of the expected S21 of the 6Ω resistor connected with the T junction; in the resistor model, use C, L and R measured in 1.6. Report the used model and the meaningful relations. Plot |S21| comparing the measurements with the model expectations. **(REPORT)**

3. REFLECTION MEASUREMENTS ON A SHUNT CAPACITOR

Consider the capacitor installed on a T junction, with a 50 Ω terminated port; the model is shown in Fig. b. **Use the 300kHz-300MHz span**.

3.1 Visualize S11 on the Smith Chart and use the markers to measure the main points. **(VERIFY WITH THE PROFESSORS)**.

3.2 Write the admittance Y of the component according to the model reported in Fig. b. In particular, express the behavior of Y for low frequencies. **(REPORT)**.

In the measurements, use the equation to convert S11 to Y:

$$Y = 1 / (50 (1 + S11)/(1-S11)) \quad (4)$$

3.3 From Im(Y) and by interpolating data at low frequency, deduce C with uncertainty **(REPORT)**.

3.4 From Real(Y) and by interpolating data at low frequency, deduce R with uncertainty **(REPORT)**.

3.5 Save S11, Re(Y), Im(Y). Compare the plots of Re(Y), Im(Y) with those obtained by applying Eq. 4 and the measurements of S11.

3.6 Plot |S11| (**linear scale**) and the Smith Chart by overlapping the measures and the results of the model in Fig. b **(REPORT)**.

4. TRANSMISSION MEASUREMENTS ON A SHUNT INDUCTOR

Consider the inductor installed on a T junction; **draw the circuit model**. **Use the 300kHz-300MHz span**.

4.1. Report, as a function of the frequency, the analytical expression of the measured S21 between the 2 open ports of the T-junction. Report also the expression of |S21| **(REPORT)**.

4.2. From the measurement of |S21| (**linear scale**) and from its linear fit at low frequency, deduce a value of L with uncertainty **(REPORT)**.

4.3. Report the measurements of |S21| (linear scale) and ∠S21 (with maximum frequency equal to 300MHz) overlapped to the theoretical plot obtained, using for L the measurement in point 4.2 (REPORT).

5. NOMINAL REFLECTION MEASUREMENTS ON A RESISTOR OF R = 230 Ω (OPTIONAL)

Repeat the measurements of point 1 for the resistor of 230 Ω. **Use the 300kHz-1.5GHz span.**

PAY ATTENTION because the L term can be neglected (as we saw in the lectures) and the C term can be measured from the Im(Y) slope, since the equivalent circuit of the resistor terminated with a short circuit is entirely comparable with the one showed in Fig. b **(REPORT)**.