RF Engineering
A very brief Introduction into *QucsStudio*

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Circuit Simulation

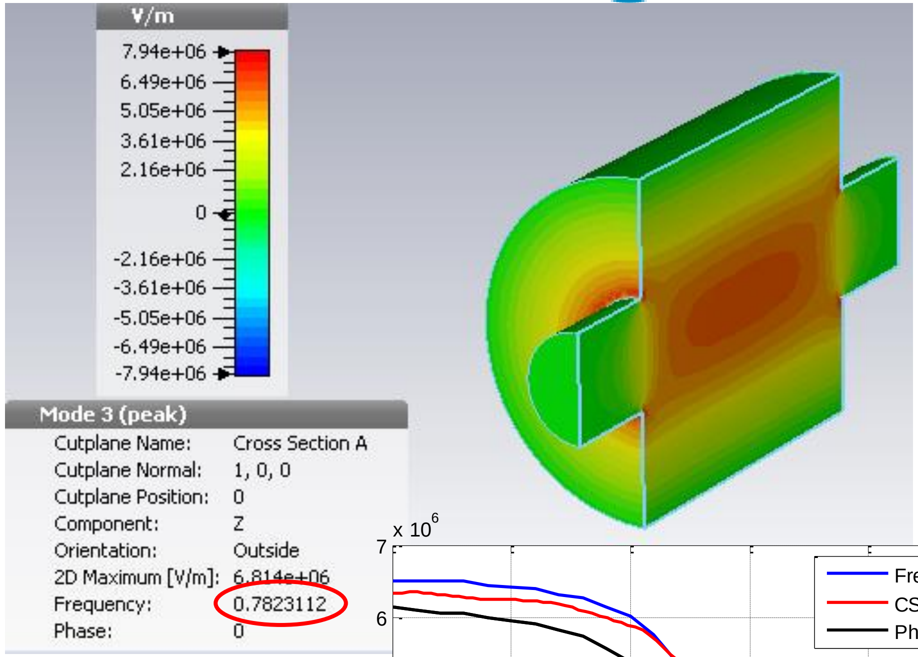
- **Three ways to analyze a RF subsystem or component**
  1. **Applying Maxwell's equations, analytical (if possible), but usually numerically**
  2. **Approximation by an equivalent circuit, to be analyzed analytically or numerically**
  3. **Building the RF subsystem or component, and characterize it by measurements**
- **In an ideal world all three methods will agree**

- **Even simple equivalent circuit problems quickly become too complicated to be solved analytically**
  - **Industry offers a large variety of numerical circuit and system simulation tools, e.g., Advance Design System (ADS), Microwave Office, many SPICE variants, etc.**
    - Some include EM *Maxwell* solvers, linear, transient and harmonic balance solvers, and digital signal processing and system design including FPGAs
  - **Freeware tools, e.g., Qucs, Qucs-S, QucsStudio, LTSpice, Ngspice, SPICE, etc., have many limitations, but are educationally valuable!**

Example: Pillbox TM010 Mode

- **A cylindrical resonator was analyzed numerically and by measurement characterization:**

Method	Q_0 value	R/Q	R_{shunt} (MΩ)
Frequency shift	6180.3	15.54	9.6
Phase shift		16.55	10.2
CST	6408.4	13.21	10.1
From CST electric field		14.61	9.5

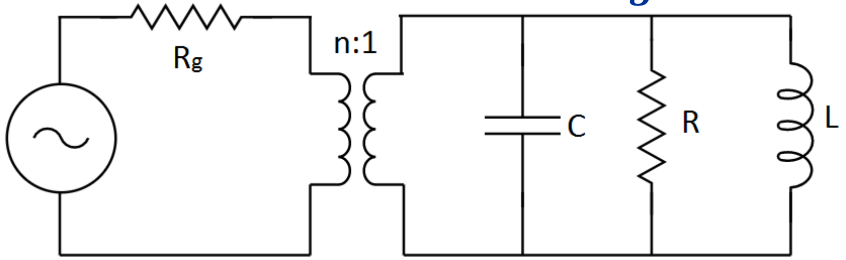


- **We can extract the values of an equivalent RLC parallel circuit for critical coupling ($R_g = 50\ \Omega$):**

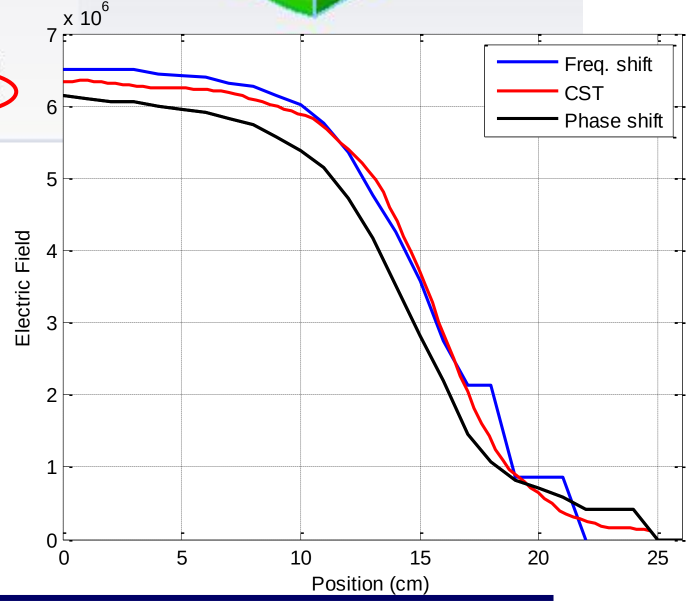
$$R = \frac{R}{Q} \cdot Q$$

$$\omega_0 = \frac{1}{\sqrt{LC}}$$

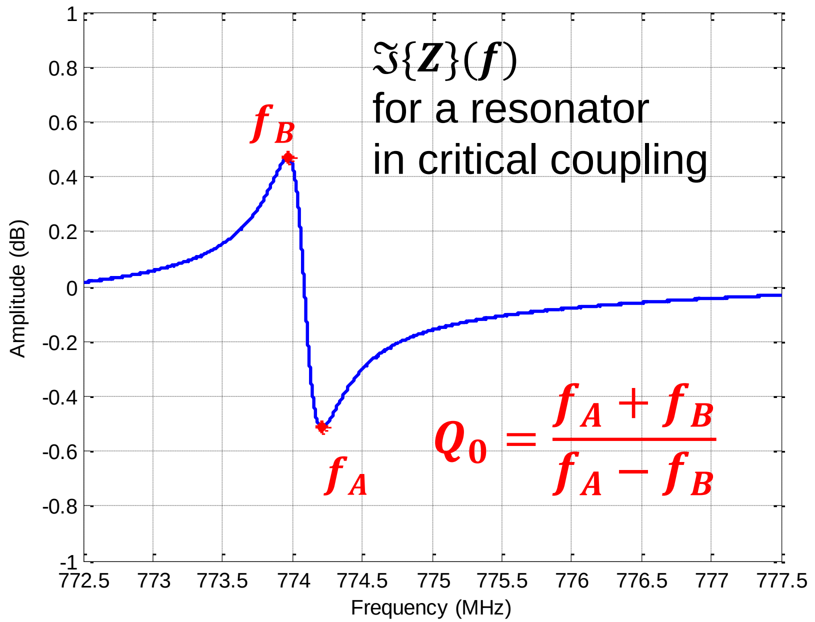
$$Q = \frac{R}{\omega_0 L} = R \cdot \omega_0 C \qquad n = \sqrt{R/R_g}$$

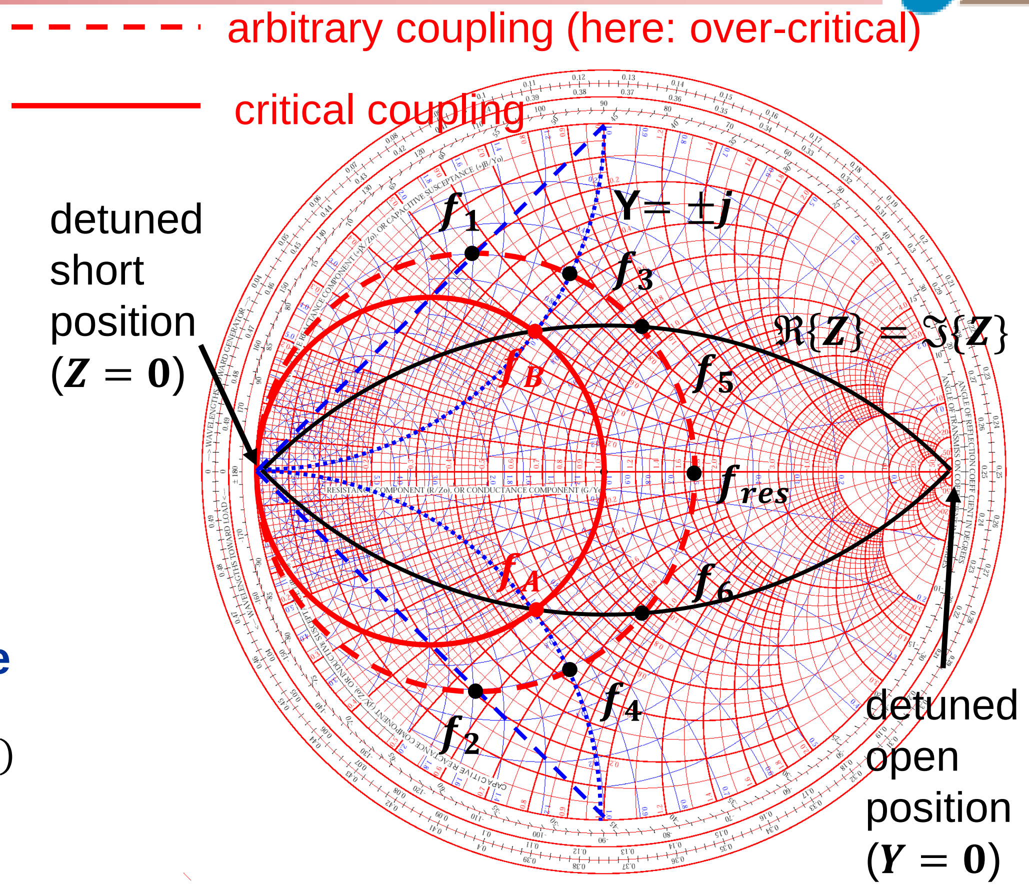


Element	Value
R	84.655 kΩ
L	2.6883 nH
C	15.405 pF
n	41.14



Q-factor from S_{11} Measurement





- **Correct for the uncompensated effects of the coupling loop**
  - **Electrical length adjustment: "straight" $\Im\{Z\}(f)$**
- **Adjust the locus circle to the detuned short location**
  - **Phase offset**
- **Verify no evanescent fields penetrating outside the beam ports**
  - **i.e., no frequency shifts if the boundaries at the beam ports are altered**

Frequency marker points in the Smith chart:

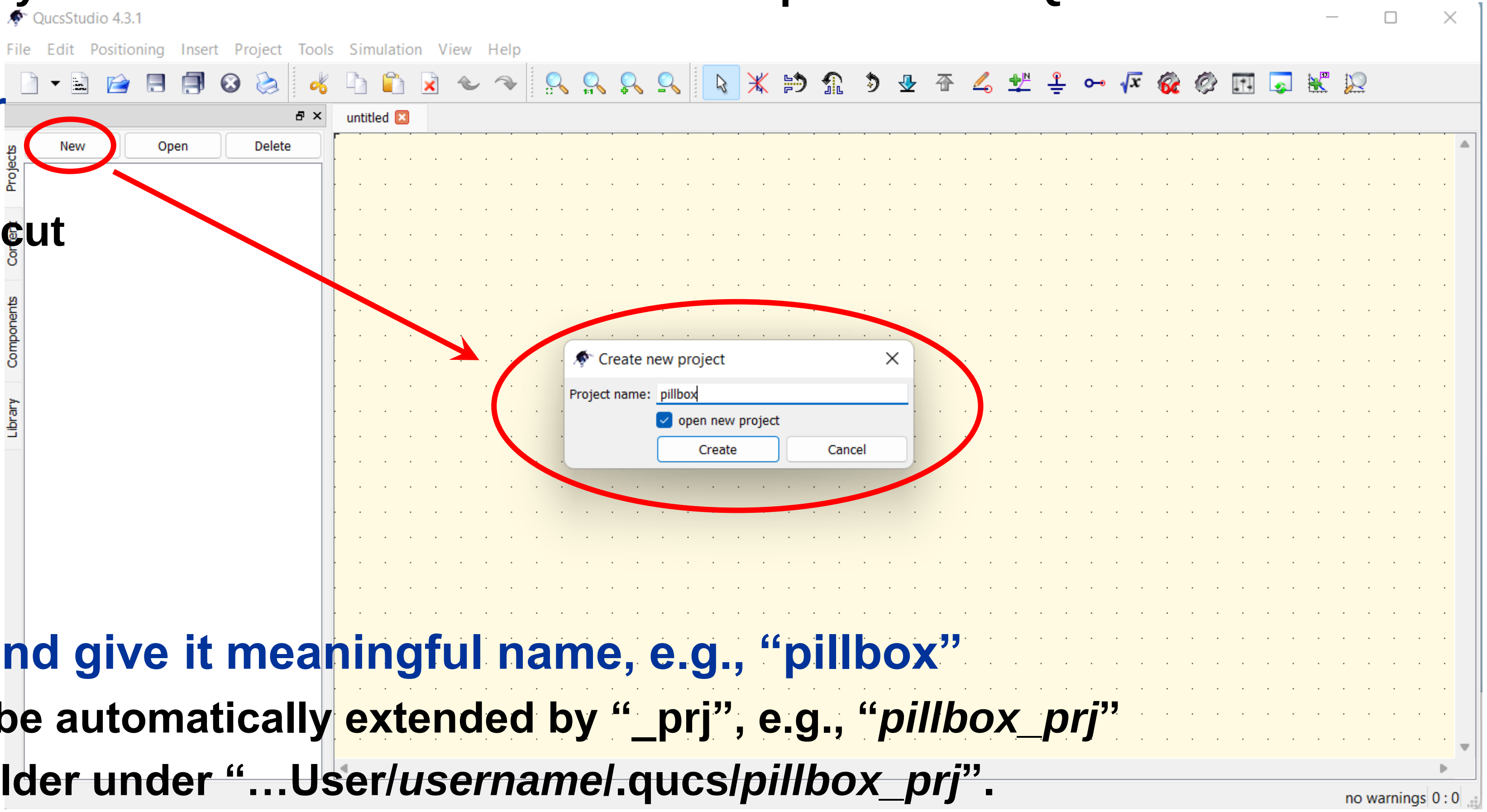
$f_{1,2}$: $\Im\{S_{11}\} = max.$ to calculate Q_L

$f_{3,4}$: $Y = \Re \pm j$ to calculate Q_{ext}

$f_{5,6}$: $\Re\{Z\} = \Im\{Z\}$ to calculate Q_0

QucsStudio (1)

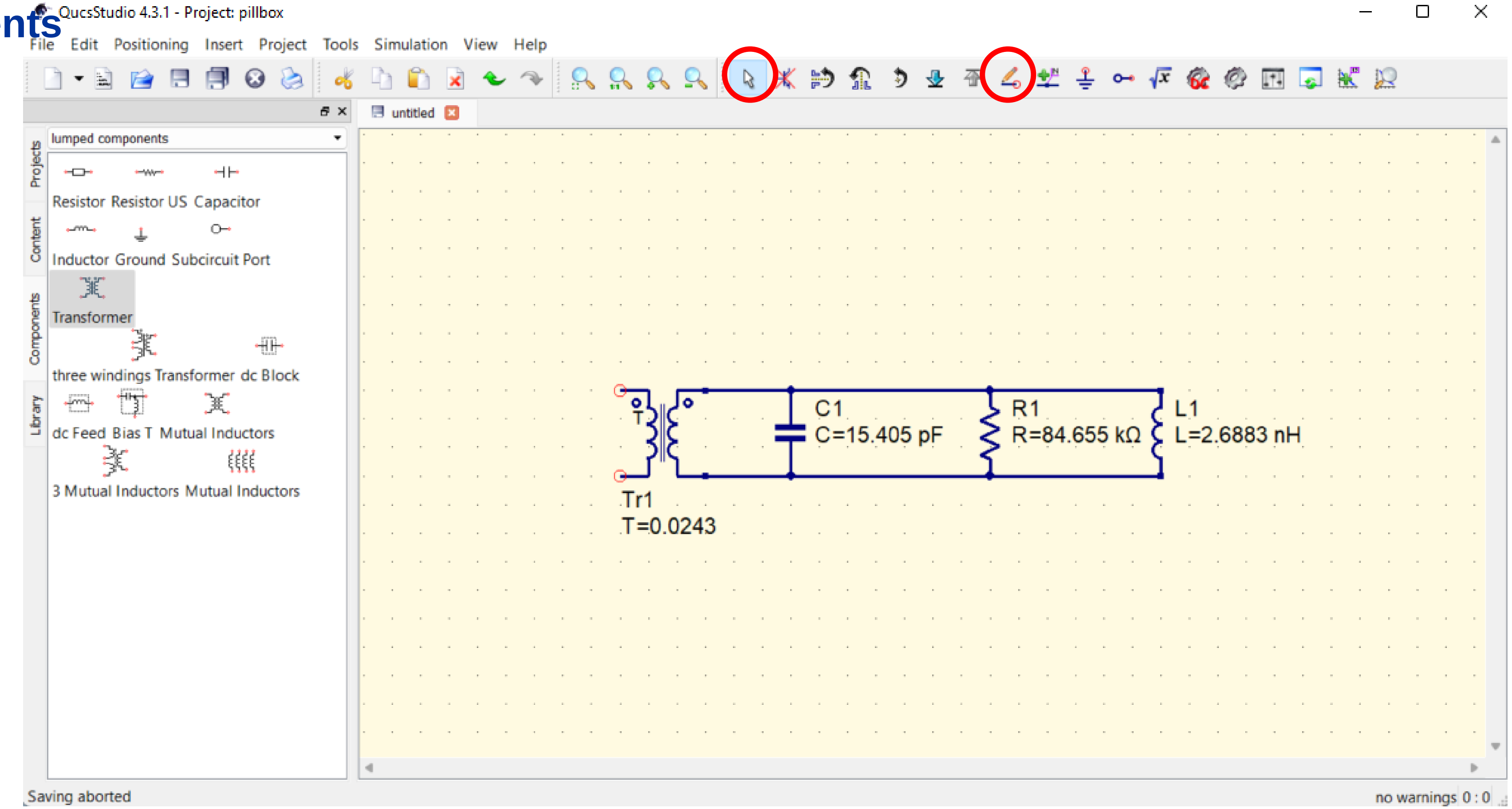
- **Is a better maintained derivate of Qucs**
  - **Runs unfortunately only under Windows and files are incompatible with Qucs**
- **Locate “start.bat” in the installation folder to start the program**
  - **Eventually link a shortcut on the desktop screen for convenience**



- **Open a “New project” and give it meaningful name, e.g., “pillbox”**
  - **The project name will be automatically extended by “_prj”, e.g., “*pillbox_prj*”**
  - **You find the project folder under “…User/*username*/.qucs/*pillbox_prj*”.**

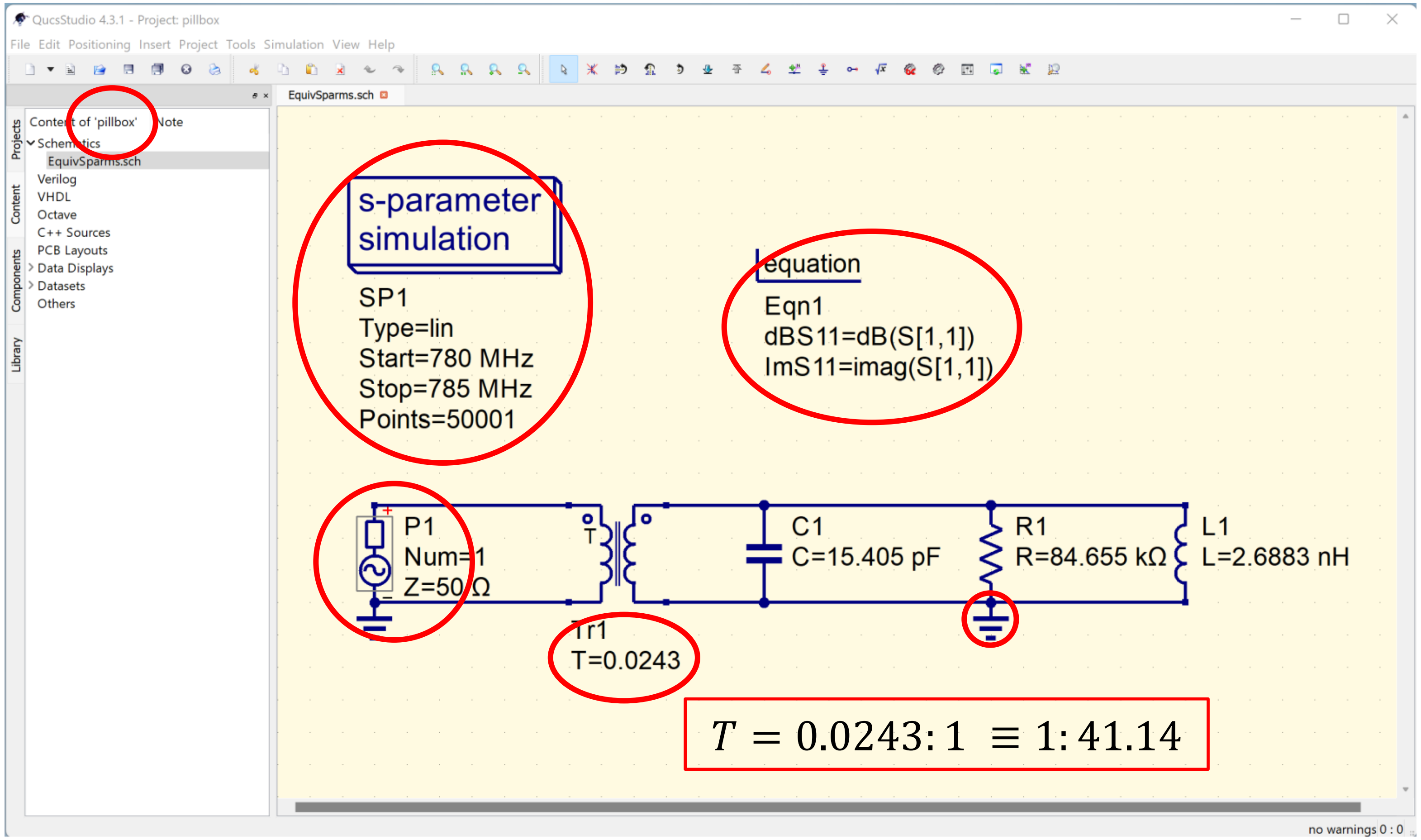
QucsStudio (2)

- Locate the "Component" tap and select "lumped components" from the drop-down bar (default)
- Select your components on the schematics screen and edit the values
  - Use "esc" to unselect an action
- Wire up the components



QucsStudio (3)

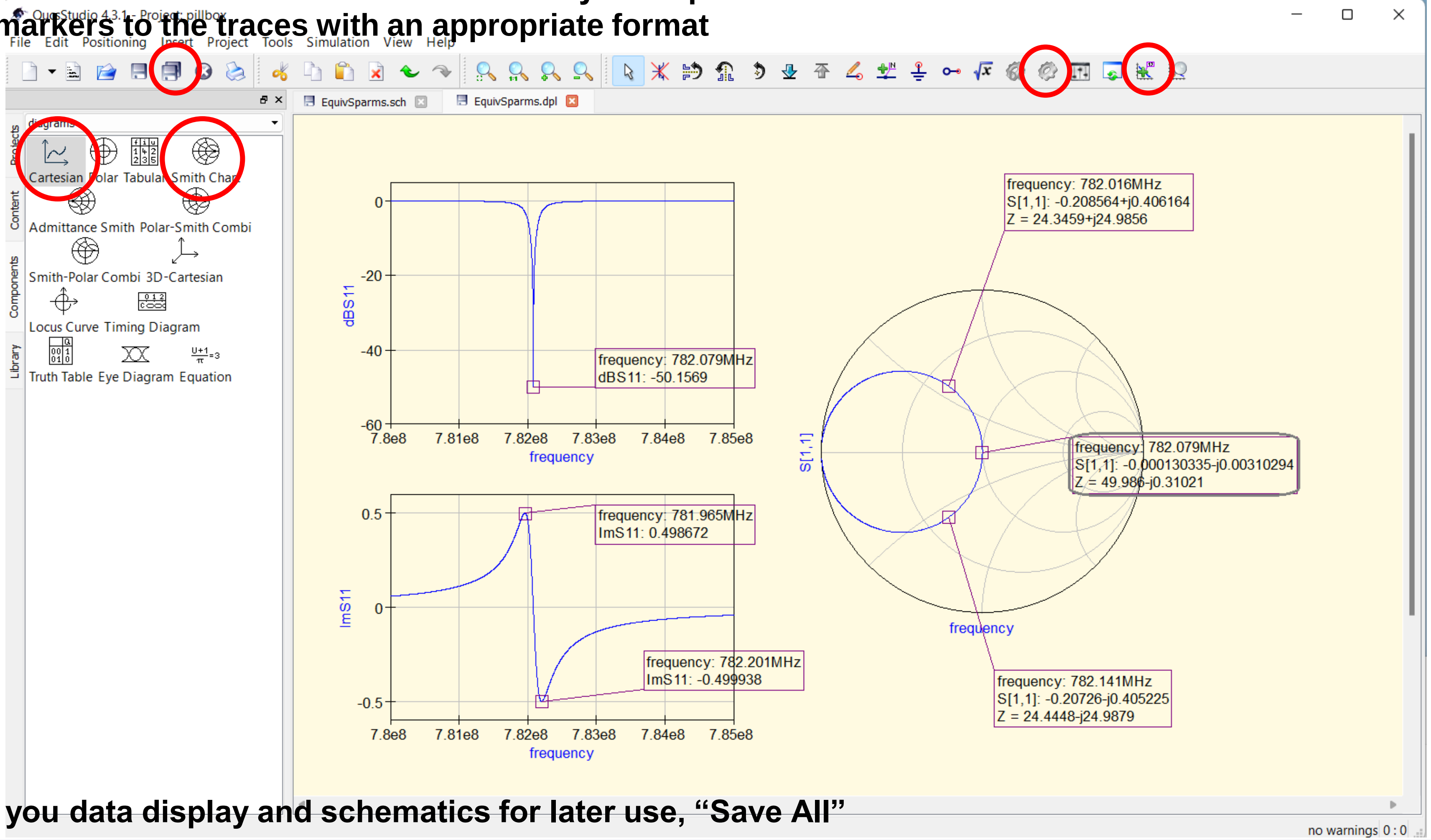
- **Finalize the schematics input by adding**
  - **"power source" and "s-parameter simulation", grounding, "equation" for dBS11 and ImS11**



  - **Save your schematic under a meaningful name**

QucsStudio (4)

- **Execute the "simulation" and display the results using "Cartesian" and "Smith Charts" plots**
  - **Use the "dBS11"and "ImS11" data defined by the equations**
  - **Add markers to the traces with an appropriate format**



  - **Save you data display and schematics for later use, "Save All"**