5XTC0, Components in wireless technologies

Module 5: Lab QUCS RF Amplifier design/simulation

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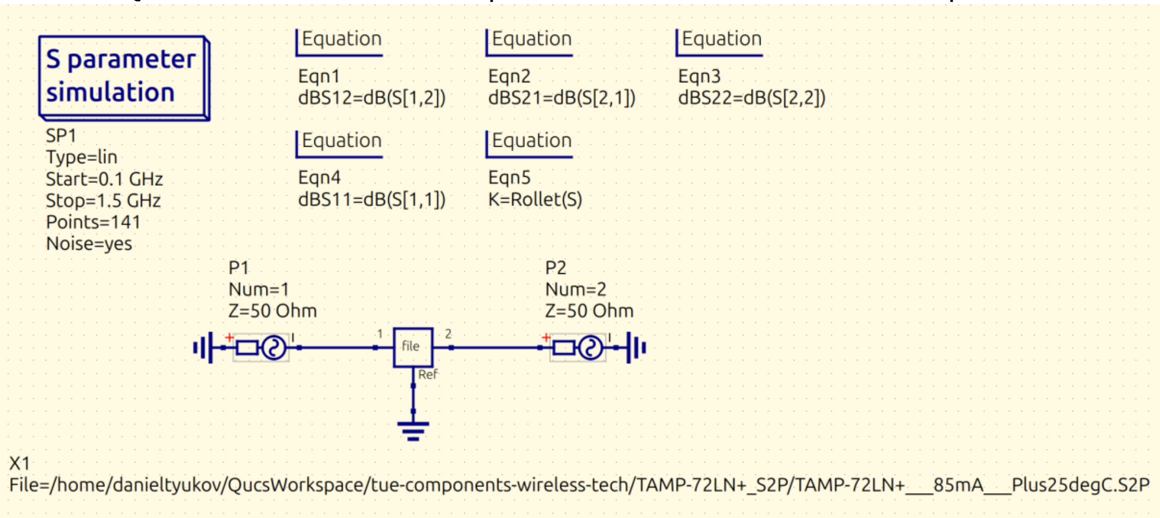
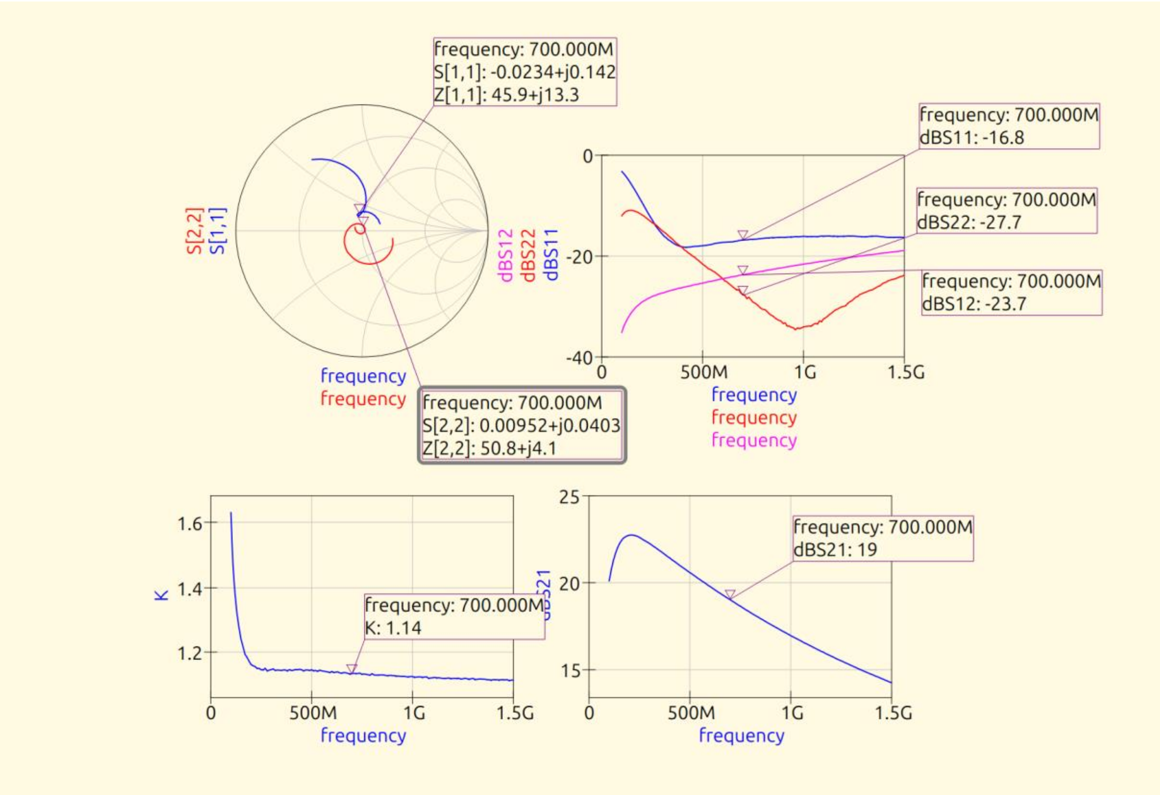
Assignment Lab 5: QUCS RF Amplifier design/simulation.

Tasks stand-alone amplifier (slide 4):

1. Create a QUCS schematic with the s-parameter file of the standalone amplifier.



2. Simulate the schematic to display the 4 S-parameters and stability factor, see slides. Show your data display below. Place markers at 700 MHz.



Assignment questions (slide 5):

1. **Explain the meaning of:**
   - **S11, S12, S21, S22**

     1..1. **S11** – Input reflection coefficient. Tells you how much of the incoming signal at the input port is reflected.

     1..2. **S12** – Reverse transmission (isolation). Tells you how much signal couples “backwards” from the output port to the input.

1..3. **S21** – Forward transmission (gain). Tells you how much of the input signal actually makes it to the output.

1..4. **S22** – Output reflection coefficient. Tells you how much of the signal at the output port is reflected toward the amplifier.

- **K Factor**
  The Rollet (K) factor is used to determine if a transistor amplifier is unconditionally stable at a given frequency. If (K > 1) (and (Delta < 1), where \(Delta) is another stability parameter), the amplifier is unconditionally stable for that frequency band. In other words, it will not oscillate regardless of what source or load impedance is applied.

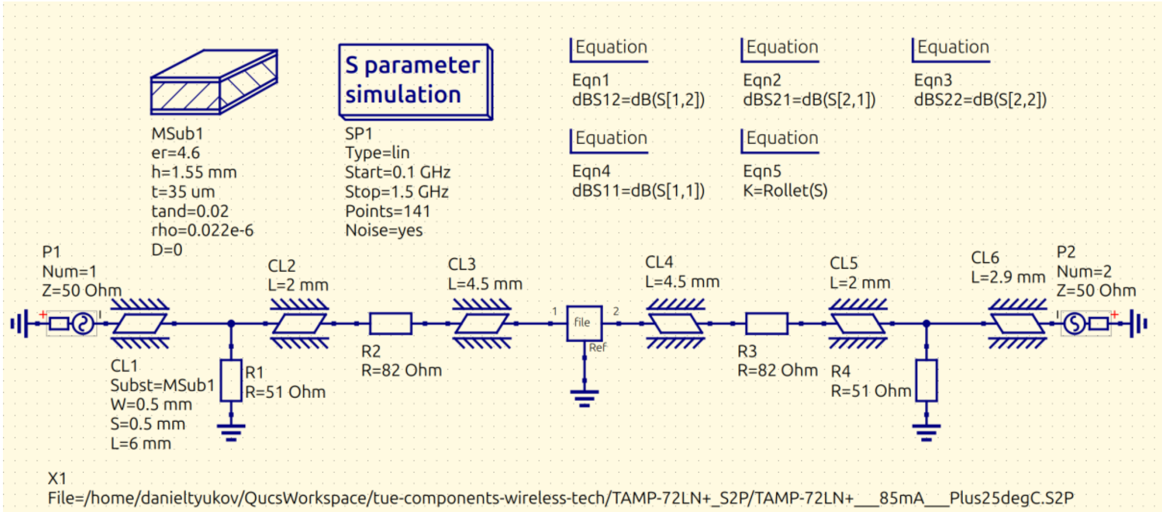
2. **What is the frequency range where the amplifier can be used?**
   Mini-Circuits datasheet for the TAMP-72LN+, is specified for operation in the 400 MHz to 700 MHz range.

3. **You did not need to provide biasing, why?**
   No need to provide any external bias networks or matching components because this amplifier module is sold with **internal bias** and matching circuitry. The S-parameter file used in simulation already accounts for the internal bias conditions (e.g., 5 V, 85 mA). Essentially, Mini-Circuits has integrated the necessary internal bias circuits, so a simple 5 V supply is all that is needed.

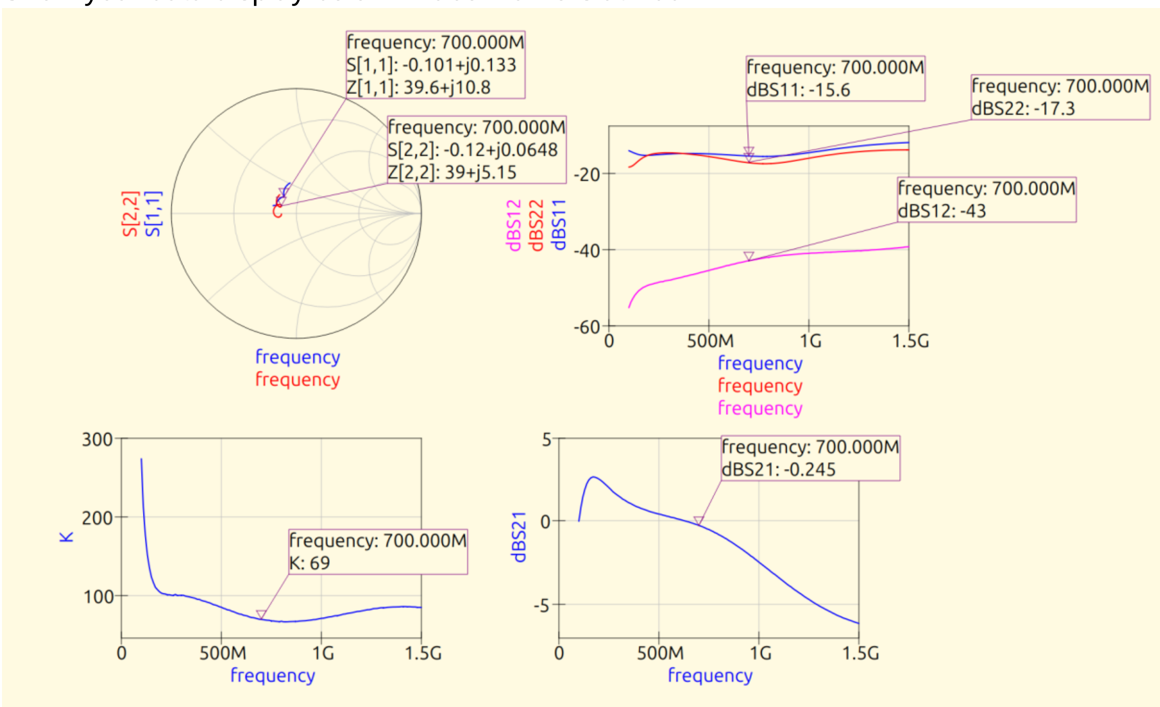
4. **Are there any differences between your simulation results and the information provided in the datasheet?**
   At 700 MHz, both the simulation and the datasheet provide values for gain (dBS21), input and output return loss (dBS11 and dBS22, derived from VSWR), and show that the amplifier is unconditionally stable (K > 1). The simulated gain is 19 dB, which closely matches the datasheet value of 18.72 dB. The simulated input return loss (dBS11) is -16.8 dB, corresponding well to the datasheet input VSWR of 1.41:1, which equates to approximately -15 dB return loss. Similarly, the simulated output return loss (dBS22) is -27.7 dB, aligning with the datasheet output VSWR of 1.09:1, approximately -27.7 dB return loss. The stability factor K is 1.14 in the simulation, consistent with the datasheet's specification of unconditional stability. Overall, the simulation results closely match the datasheet values, with only minor expected deviations.

Tasks amplifier board (slide 6/7):

3. Create a QUCS schematic of the whole board with the s-parameter file of the standalone amplifier.



4. Simulate the schematic to display the 4 S-parameters and stability factor, see slides. Show your data display below. Place markers at 700 MHz.



Assignment questions (slide 8):

Explain the differences between simulations of the amplifier board with and without resistors.

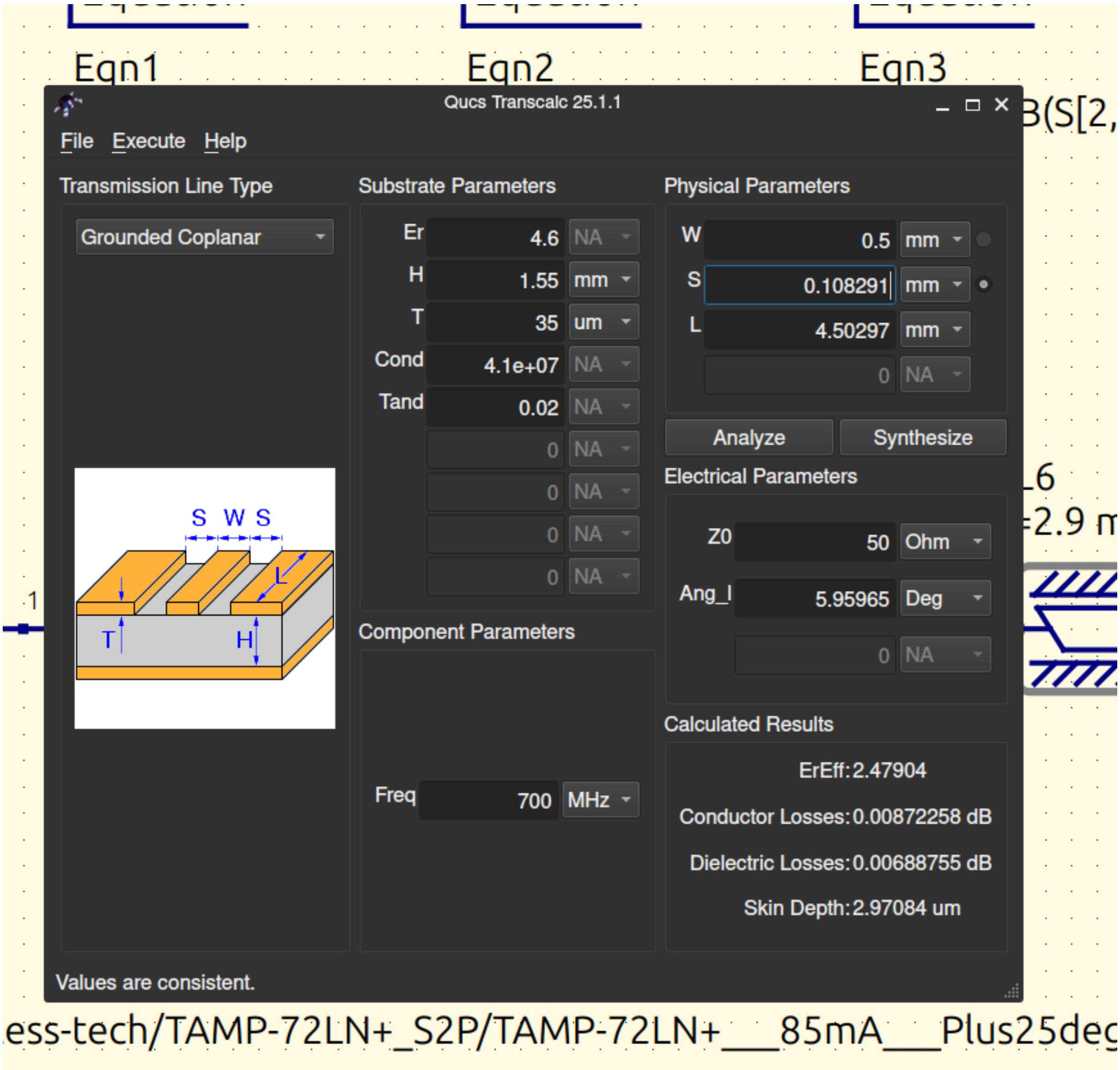
5. **Why have the S11 & S22 changed? Are they improved or not?**
Resistors disrupt the impedance matching at input/output. Originally, without resistors, **Z[1,1] = 45.9 + j13.3 Ω** and **Z[2,2] = 50.8 - j4.1 Ω** (close to 50 Ω). With resistors, these shift to **39.6 + j10.8 Ω** and **39 + j5.15 Ω**, causing increased reflections. Hence, **S11 = -15.6 dB** and **S22 = -17.3 dB** become worse compared to the unloaded board.
6. **Why is the S21 (gain) much lower?**
The resistors load the amplifier, dissipating signal power. The unloaded board shows

S21 = 19 dB gain, but with resistors, it drops drastically to **S21 = -0.245 dB**, effectively turning gain into attenuation.

7. **Why is the stability factor higher?**
   With resistors, the **K-factor increases to 69** (from ~1.14 unloaded). The resistors damp reactive feedback paths, suppressing potential oscillations and making the amplifier unconditionally stable.

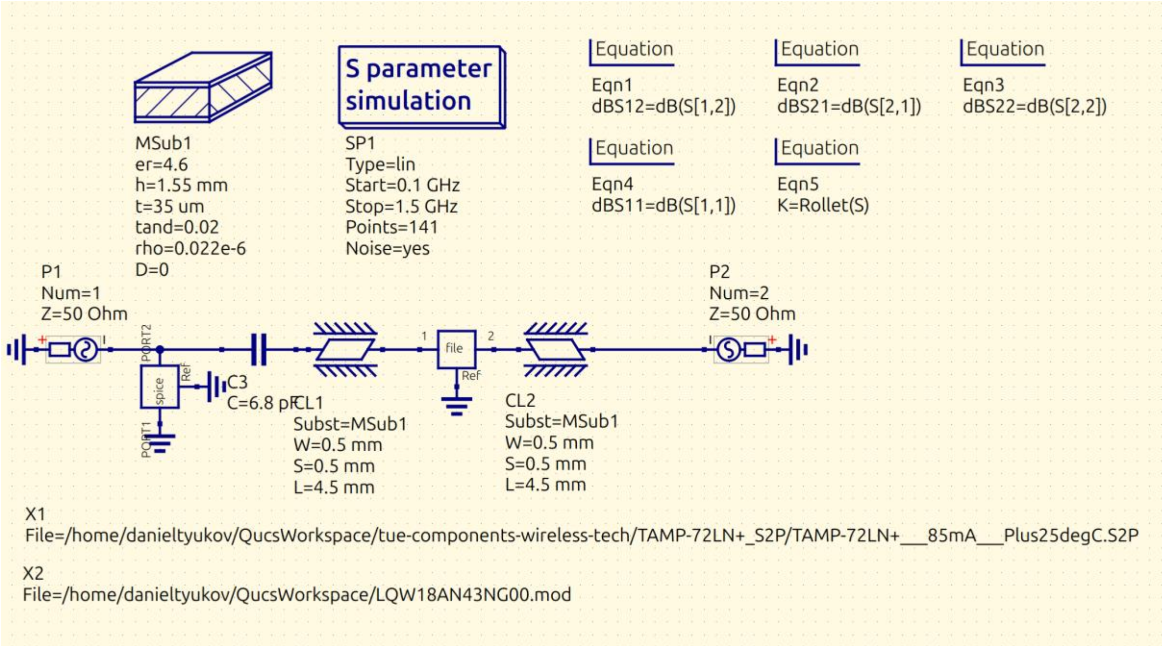
8. **What is the impedance of the transmission lines at 700 MHz?**
   At **700 MHz**, **Z[1,1] = 39.6 + j10.8 Ω** and **Z[2,2] = 39 + j5.15 Ω**. Ignoring reactance, the characteristic impedance is around **39 Ω**, lower than the ideal 50 Ω.

9. **What should have been “S” (space between transmission line and ground plane) in order to make the transmission line 50 Ohm at 700 MHz, keeping the width of the transmission line 0.5 mm?**
   0.11 mm

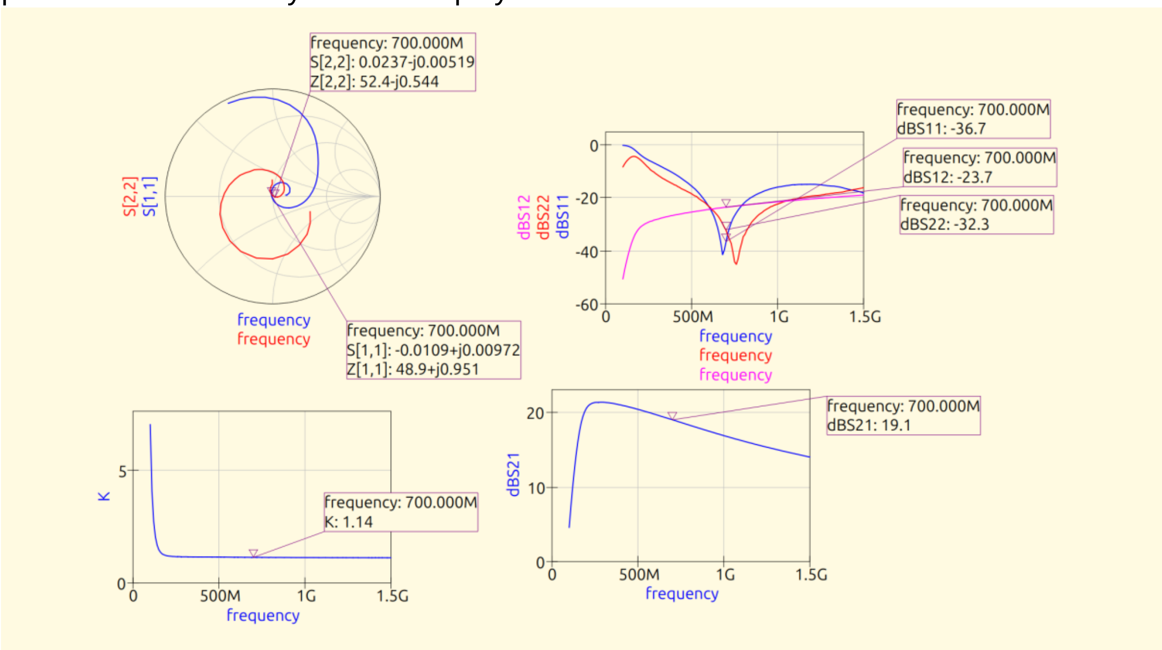

Eqn1
Eqn2
Eqn3
Qucs Transcalc 25.1.1
File Execute Help
Transmission Line Type
Grounded Coplanar
Substrate Parameters
Er 4.6 NA
H 1.55 mm
T 35 um
Cond 4.1e+07 NA
Tand 0.02 NA
Physical Parameters
W 0.5 mm
S 0.108291 mm
L 4.50297 mm
Analyze
Synthesize
Electrical Parameters
Z0 50 Ohm
Ang_l 5.95965 Deg
Component Parameters
Freq 700 MHz
Calculated Results
ErEff: 2.47904
Conductor Losses: 0.00872258 dB
Dielectric Losses: 0.00688755 dB
Skin Depth: 2.97084 um
Values are consistent.
S W S
T
H
L
ess-tech/TAMP-72LN+_S2P/TAMP-72LN+___85mA___Plus25deg

Tasks redesign amplifier board for optimal matching at 700 MHz (slide 13):

5. Redesign the QUCS schematic of the amplifier board (remove CL1, CL2, CL5, CL6 and change R1, R2, R3, R4 into L or C components.



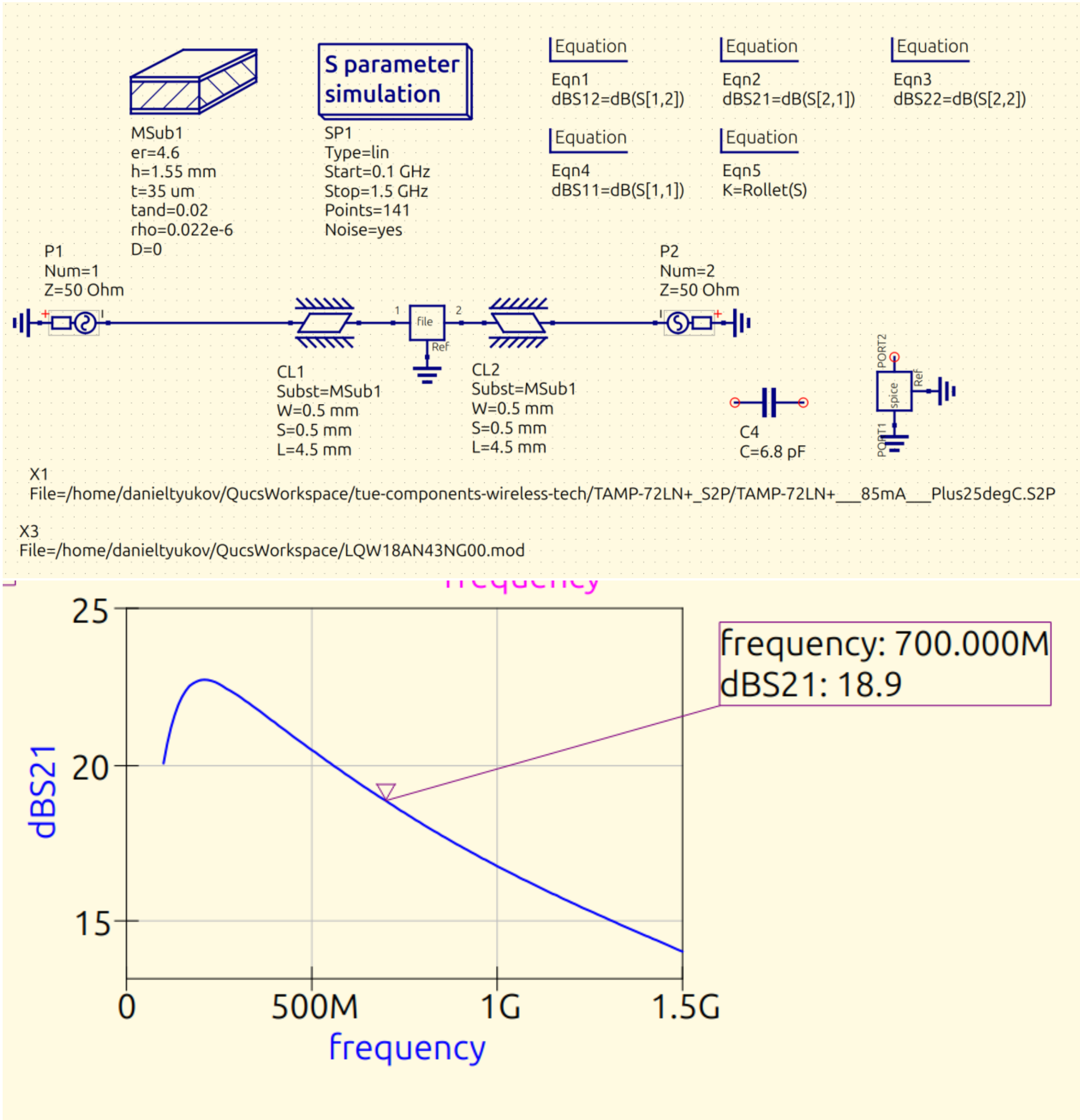
6. Simulate the schematic to display the 4 S-parameters and stability factor, like previous tasks. Show your data display below. Place markers at 700 MHz.



Assignment questions (slide 14):

Explain the differences between simulations of the stand-alone amplifier and the amplifier board.

10. **How high was the gain of the 5XTC0_V2 board originally?**
    Original gain was **19dB** on the stand-alone amplifier.
11. **And how high is the gain if we remove R1&R4 and short R2&R3 (board without resistors, unmatched)?**



The gain is **18.9dB**

12. **And how high is the gain with your redesign matched board?**
    The gain of the redesign is **19.1dB**

13. **What do you notice in the S11 / S22 curves of your redesigned matched board?**
    The redesigned matching network has minimized the refelctions on both input and output ports. The ports following a clear designated path curvature of adding a shunt inductor and then a series capacitor, and moving the prior impedance close to center of smith chart or close to the characteristic impedance of 50 Ohms.