ECE 3113

BUILDING MATCHING NETWORKS AND BILATERAL GAIN COMPUTATIONS OF AN RF TRANSISTOR

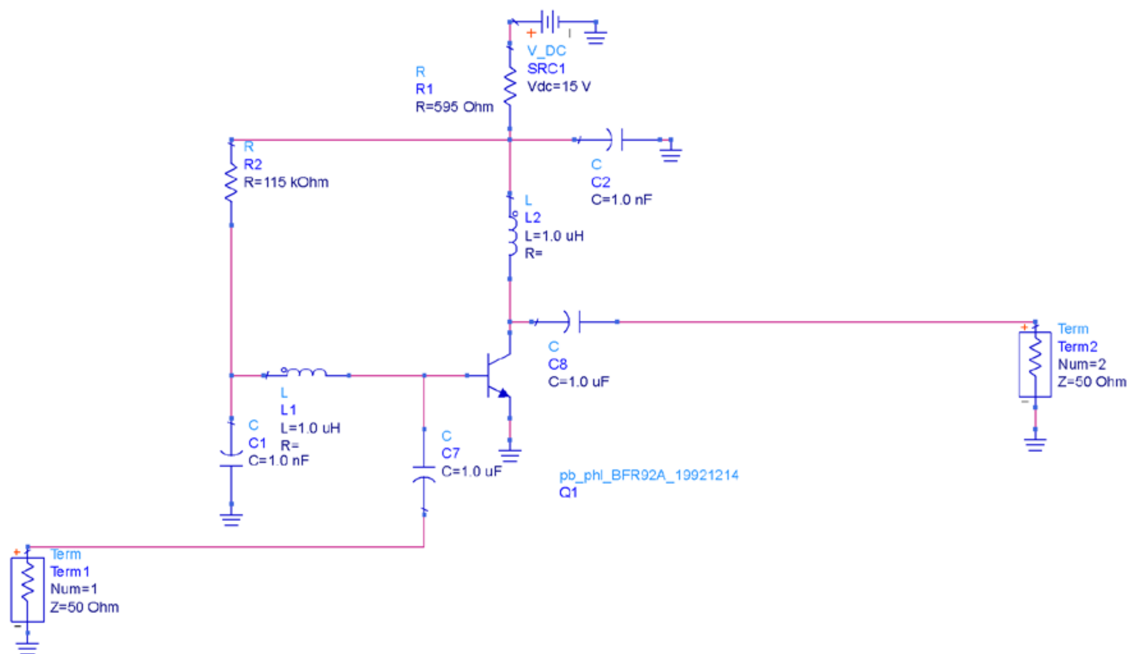
Objective

In this design we attempt to design an amplifier for maximum gain under bilateral design considerations, i.e. device feedback is included. We can carry out this objective according to the following five steps:

a) Bias the BFR92A device with a simple resistive network (R_1=595Ω and R_2=115kΩ), plus RFCs and C_B.
b) Record the S-parameters at the target frequency.
c) Determine stability, and if not stable add a series resistor at the output port. Note: If you stabilize the device, you again have to determine the S-parameters
d) Compute the reflection coefficients Γ_{MS} and Γ_{ML} based on our textbook
e) Construct lumped-element input and output matching networks.

1. Go through the above 5 steps at 1GHz and detail your work. This should include a circuit schematic with all components quantified. Run the ADS simulation and report your gain.

(a)

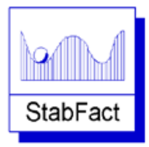


(b) S parameters at 1 GHz

freq	S(1,1)	S(1,2)	S(2,1)	S(2,2)
1.000 GHz	0.081 / -131.236	0.110 / 76.196	3.872 / 80.035	0.501 / -16.718

(c) stability test

MeasEqn
Meas1
delta=S(1,1)*S(2,2)-S(1,2)*S(2,1)



StabFact
StabFact1
K=stab_fact(S)

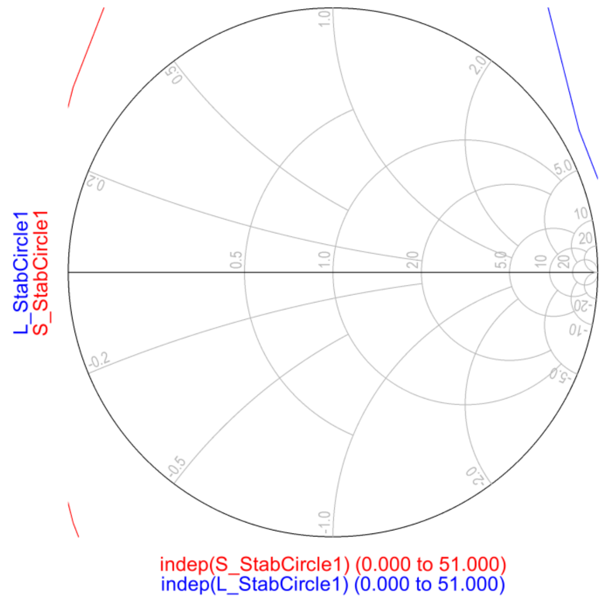
Selecting and adding these two icons from the simulation_S_parameter palette allow the calculation of Δ and K. Furthermore, we can also plot the input and output stability circles, see below.

S_StabCircle
S_StabCircle1
S_StabCircle1=s_stab_circle(S,51)

L_StabCircle
L_StabCircle1
L_StabCircle1=l_stab_circle(S,51)

After running the simulation, we obtain the following results.

freq	delta	K
1.000 GHz	0.404 / -28.527	1.064



As can be seen, the device is unconditionally stable at 1 GHz.

(d) For bilateral design, the feedback cannot be ignored. Based on our textbook, we can compute

$$\Gamma_{MS} = \frac{B_1}{2C_1} - \frac{1}{2}\sqrt{\left(\frac{B_1}{C_1}\right)^2 - 4\frac{C_1^*}{C_1}}$$

with

$$C_1 = S_{11} - S_{22}^*\Delta \quad \text{and} \quad B_1 = 1 - |S_{22}|^2 - |\Delta|^2 + |S_{11}|^2$$

and

$$\Gamma_{ML} = \frac{B_2}{2C_2} - \frac{1}{2}\sqrt{\left(\frac{B_2}{C_2}\right)^2 - 4\frac{C_2^*}{C_2}}$$

with

$$C_2 = S_{22} - S_{11}^*\Delta \quad \text{and} \quad B_2 = 1 - |S_{11}|^2 - |\Delta|^2 + |S_{22}|^2$$

Substituting the S-parameters under item (b) yields:

$$\Gamma_{MS} = -0.5537 + 0.0433\,j = 0.55 \,/\, 175.5^{o}$$

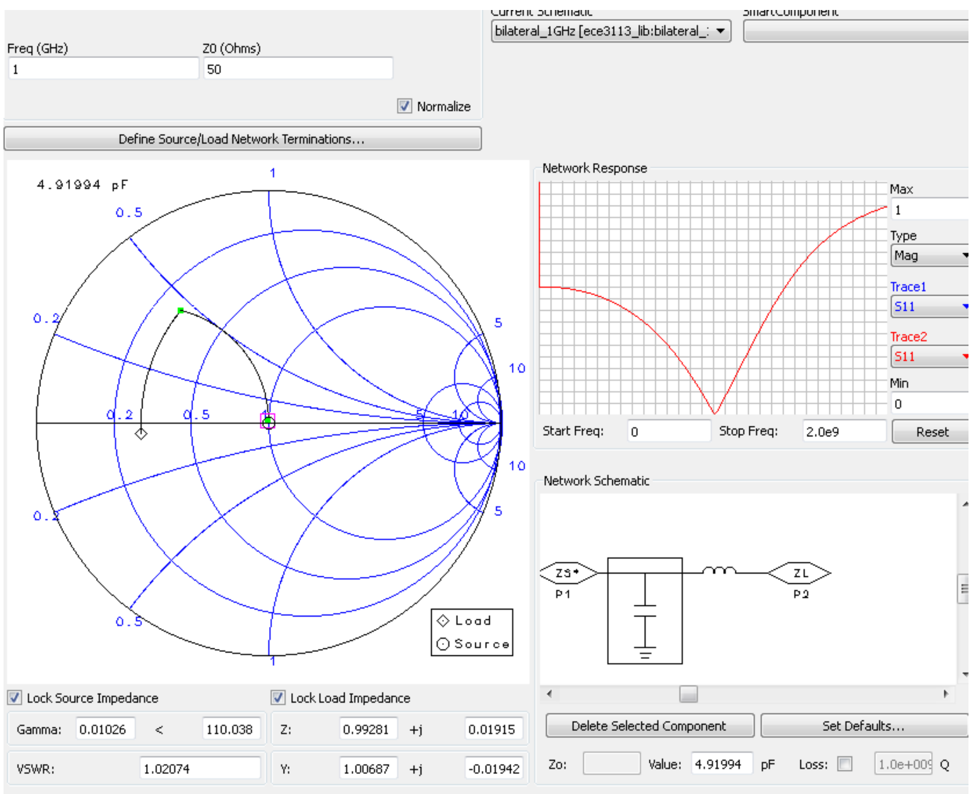
$$\Gamma_{ML} = 0.7 + 0.25\,j = 0.74 \,/\, 20^{o}$$

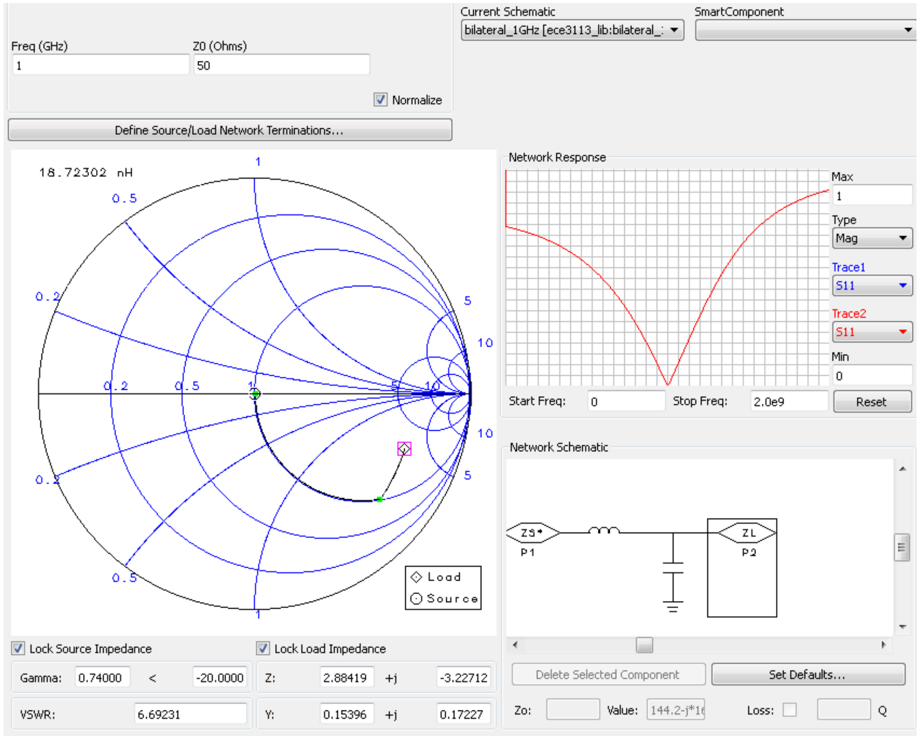
(e) Bilateral matching network at 1 GHz

The matching networks need to meet the requirements:

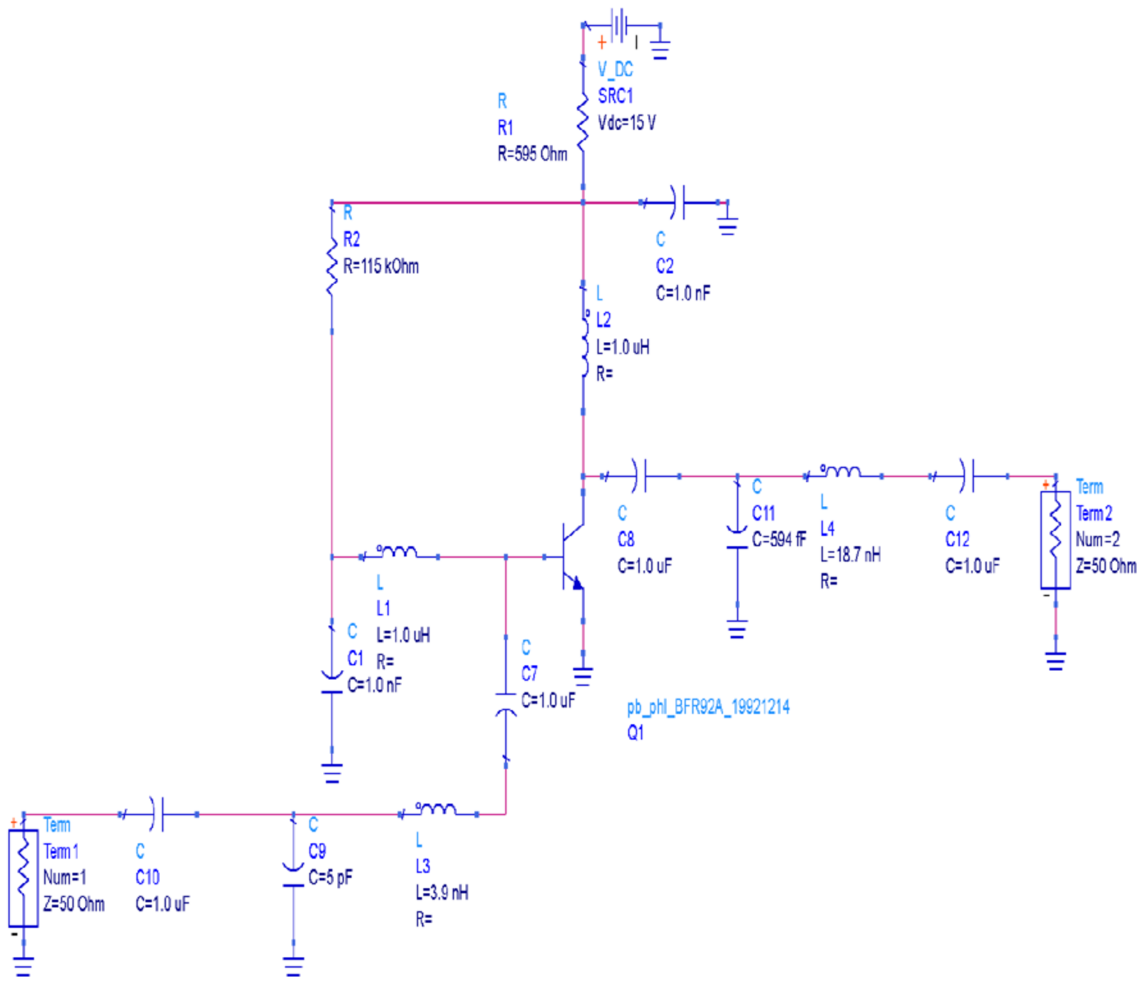
$$\Gamma_{in} = \Gamma_{MS}^{*} \quad \text{and} \quad \Gamma_{out} = \Gamma_{ML}^{*}$$

Furthermore, the input and output ports are 50 Ω. Thus,





The values for the shunt C and series L (input MN) as well as series L and shunt C (output MN) are shown in the circuit schematic.



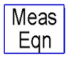
2. Repeat your work for the device at 3 GHz.

(a) The bias network is the same with the above circuit.

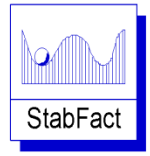
(b) S parameter at 3 GHz

freq	S(1,1)	S(1,2)	S(2,1)	S(2,2)
3.000 GHz	0.172 / 128.870	0.370 / 60.212	1.596 / 39.284	0.315 / -38.137

(c) Stability test



MeasEqn
Meas1
delta=S(1,1)*S(2,2)-S(1,2)*S(2,1)

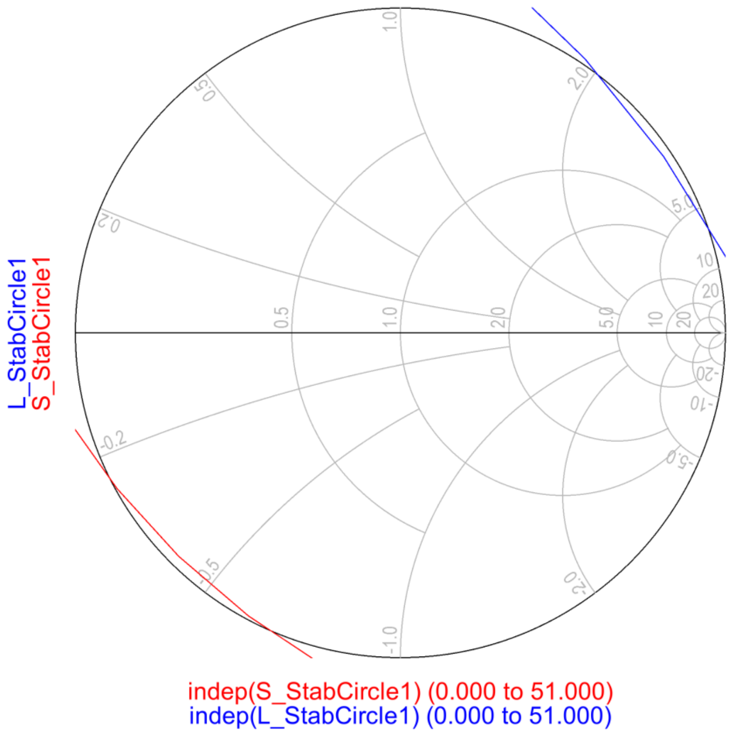


StabFact
StabFact1
K=stab_fact(S)

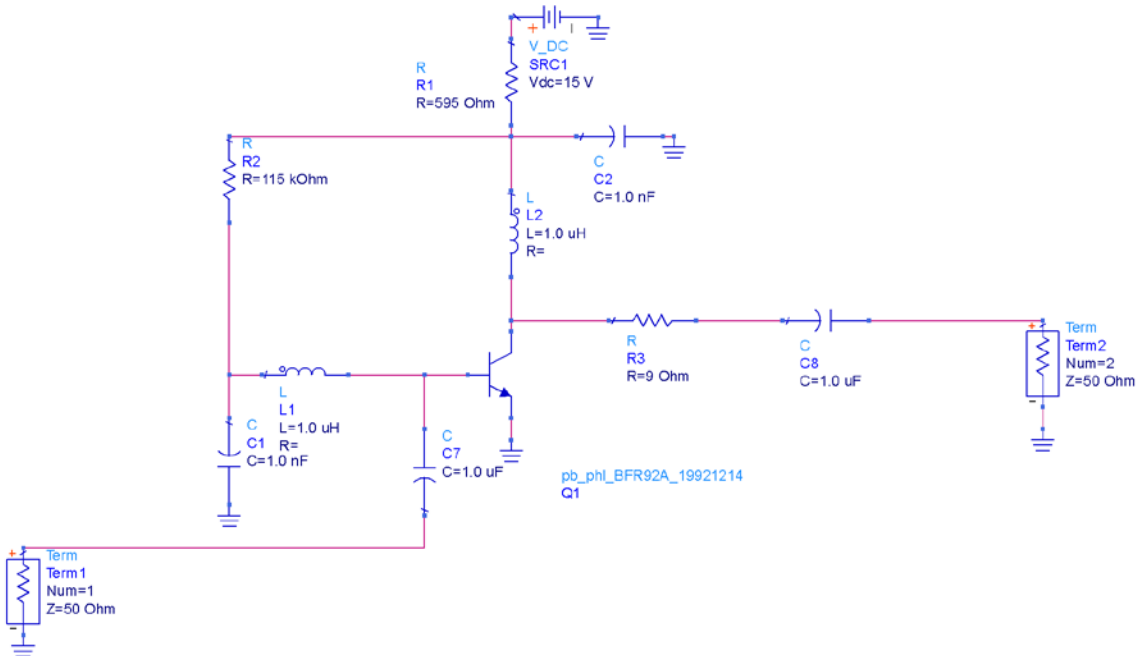
S_StabCircle
S_StabCircle1
S_StabCircle1=s_stab_circle(S,51)

L_StabCircle
L_StabCircle1
L_StabCircle1=l_stab_circle(S,51)

freq	delta	K
3.000 GHz	0.536 / -79.622	0.982



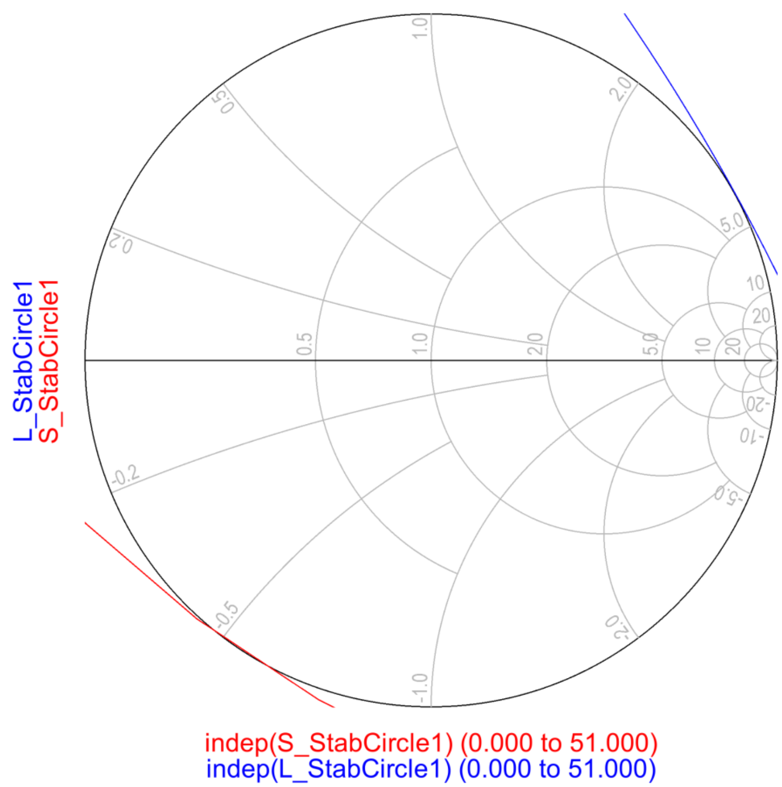
We notice, the device is not completely stable at 3 GHz. Thus, we attempt to stabilize it first by add a 9 Ω series resistor at the output.



Rerunning the simulation, we now get:

freq	delta	K
3.000 GHz	0.444 / -81.453	1.001

and



The new S-parameters that incorporate the resistor are as follows:

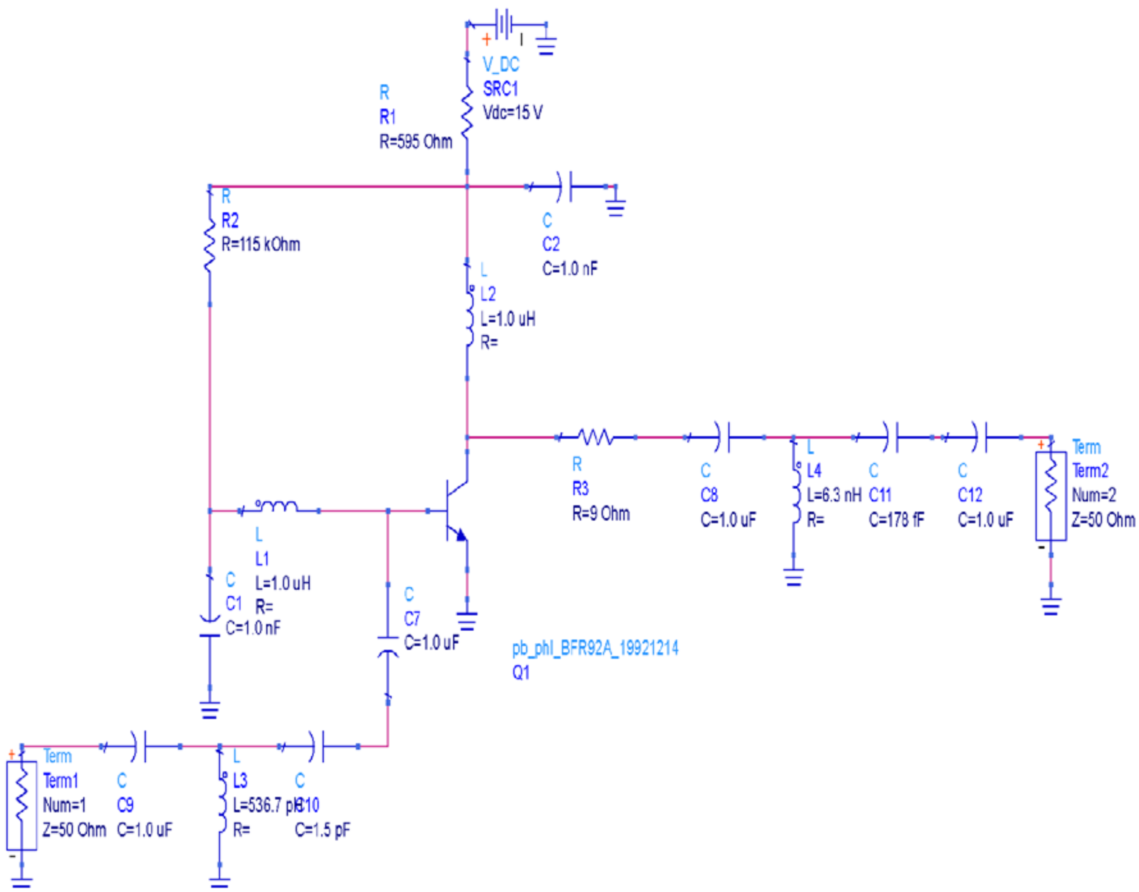
freq	S(1,1)	S(1,2)	S(2,1)	S(2,2)
3.000 GHz	0.216 / 122.203	0.346 / 59.271	1.495 / 38.344	0.339 / -30.248

(d) Using the same method:

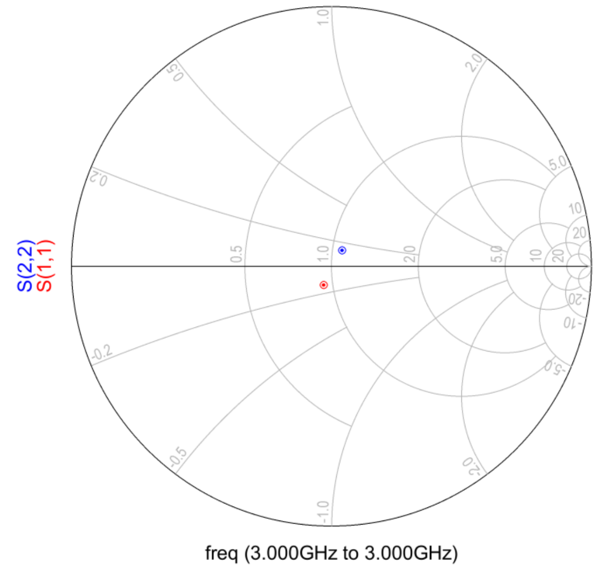
Γ_{MS} = −0.54 −0.77 j =0.94 / -125°

Γ_{ML} = 0.84 + 0.45 j=0.95/ 29°

(e) Γ_{in} = 0.94/125 ° Γ_{out} = 0.95/-29°



S_{11} and S_{22}



Tuning the output capacitor C11 to be 0.175 pF, we improve the reflection coefficients.