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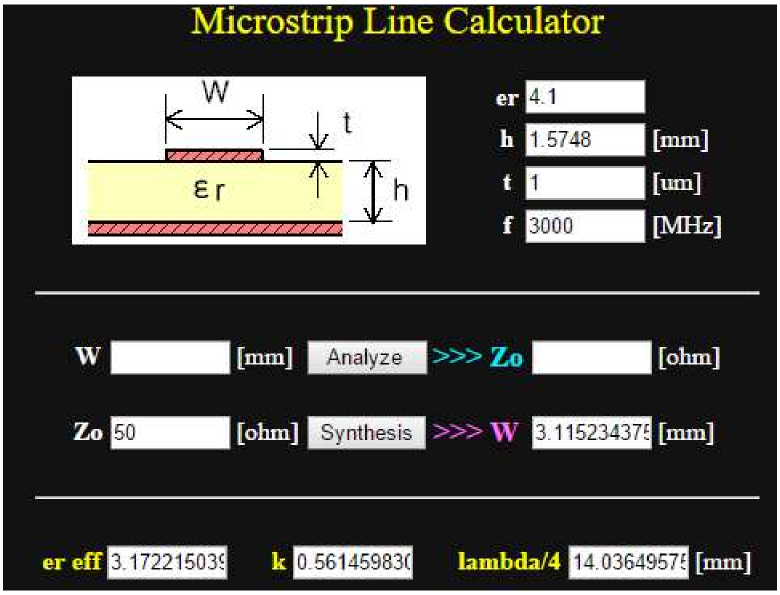
LAB 5

Task 1: Design of a TRL calibration kit.

Step1:

Using the Microstrip line calculator (http://www1.sphere.ne.jp/i-lab/ilab/tool/ms_line_e.htm) to get the physical line width of 50 ohm and quarter wavelength distance at 3 GHz.



Step2:

In order to providing a 15mm reference plane, change the parameter to parameter as following:

Thru_length= 30 mm

Reflect_length=15 mm

Line_length= 44.34 mm

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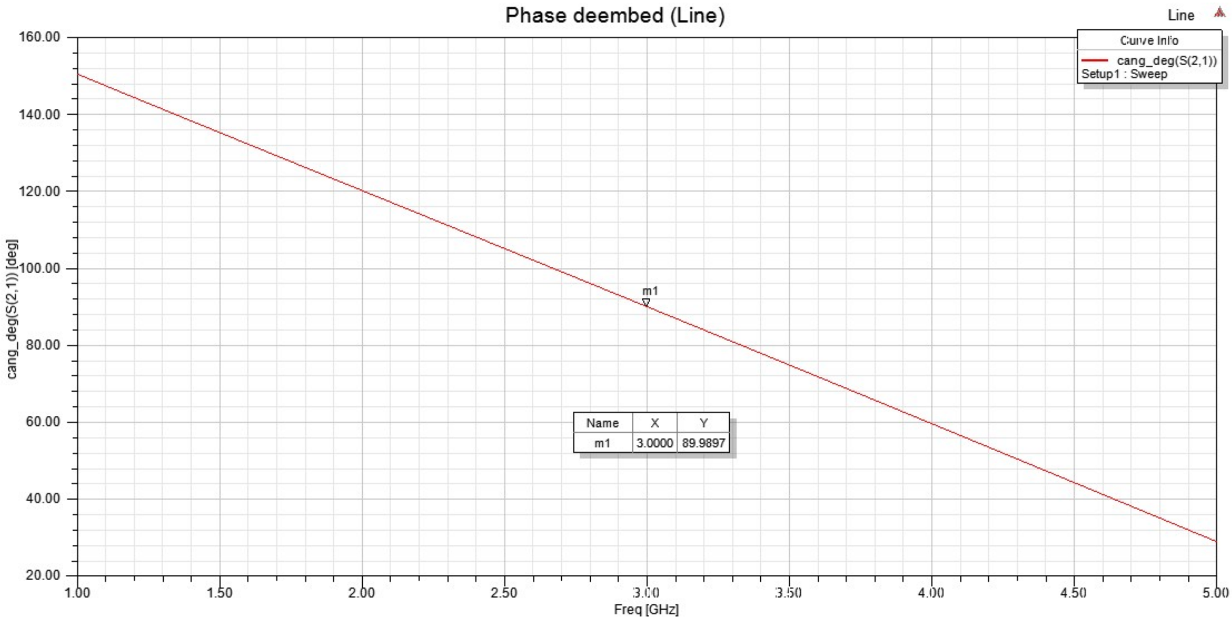
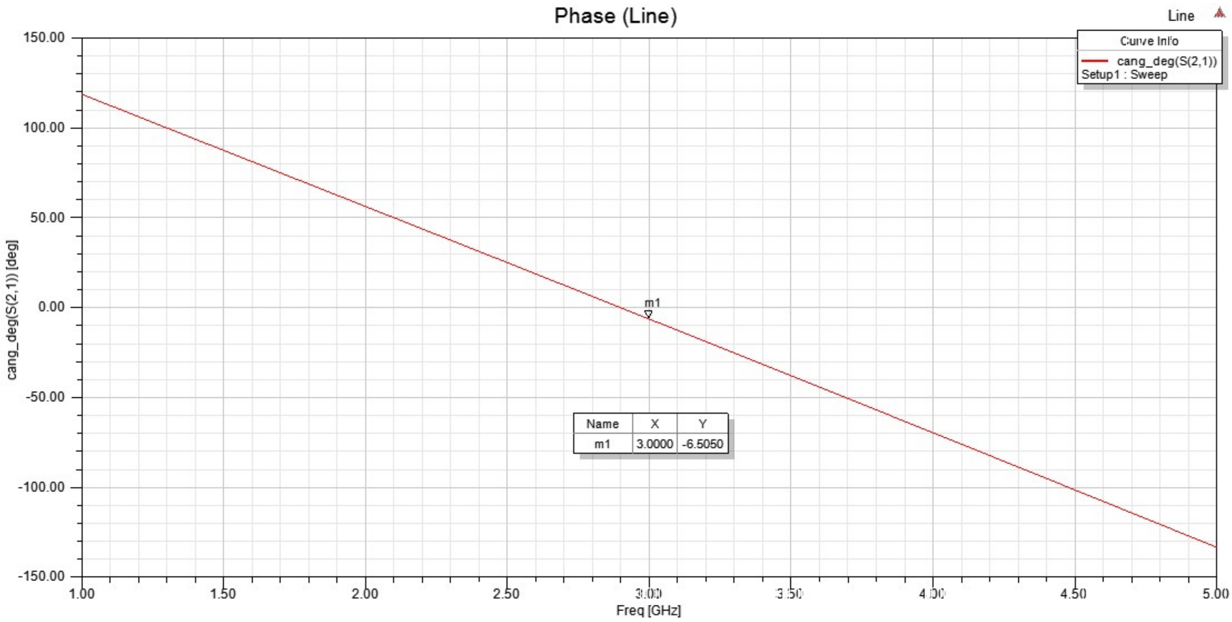
Step3:

- De-embedding length is 15 mm for each port in each model.

Simulation results of Line kit

a. Phase comparison





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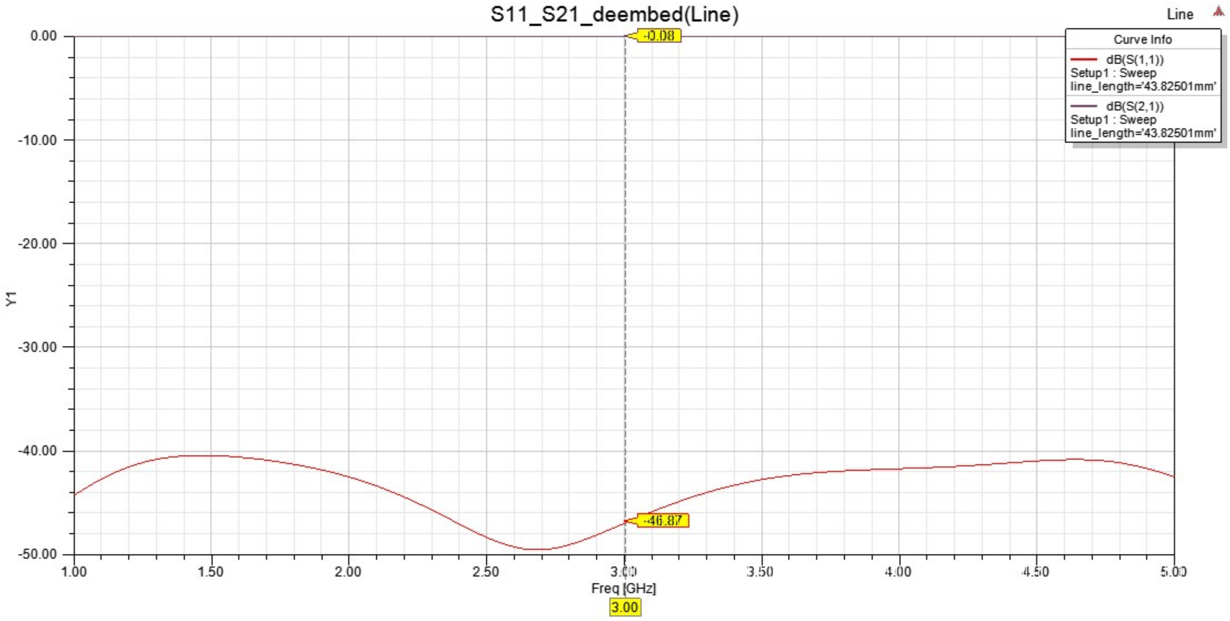
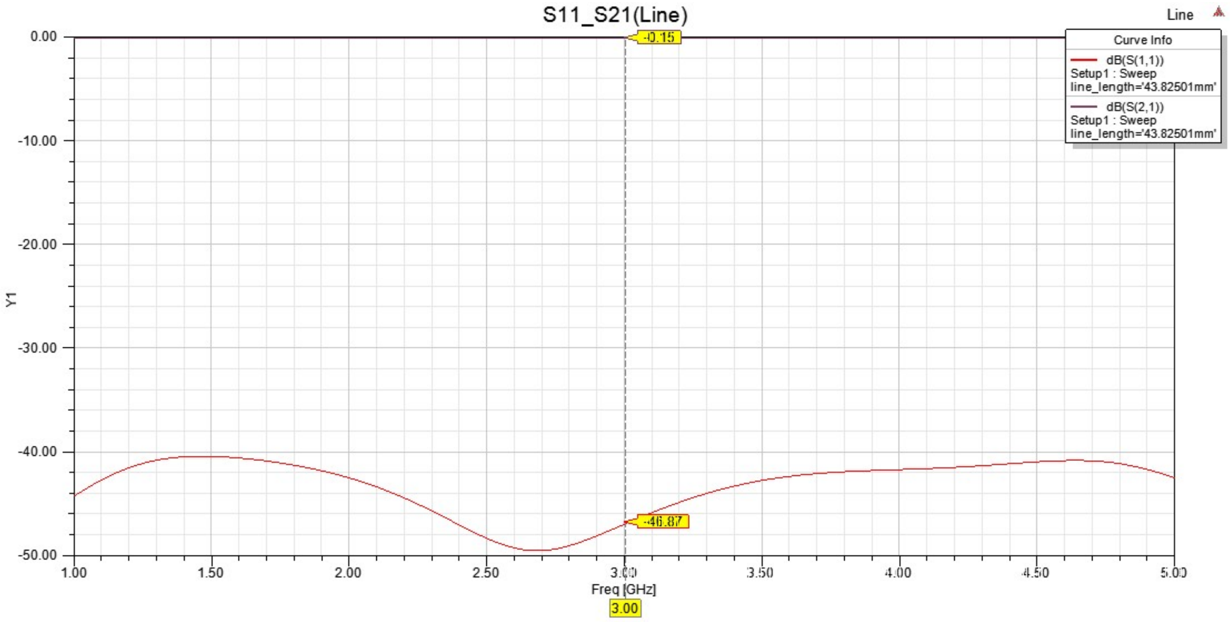
b. Magnitude comparison





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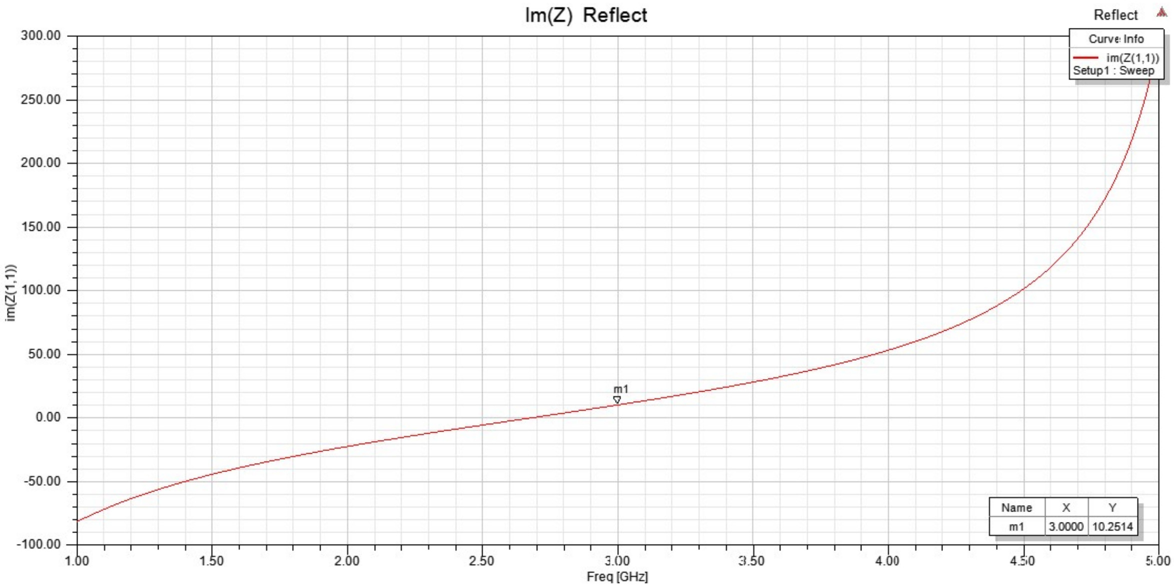
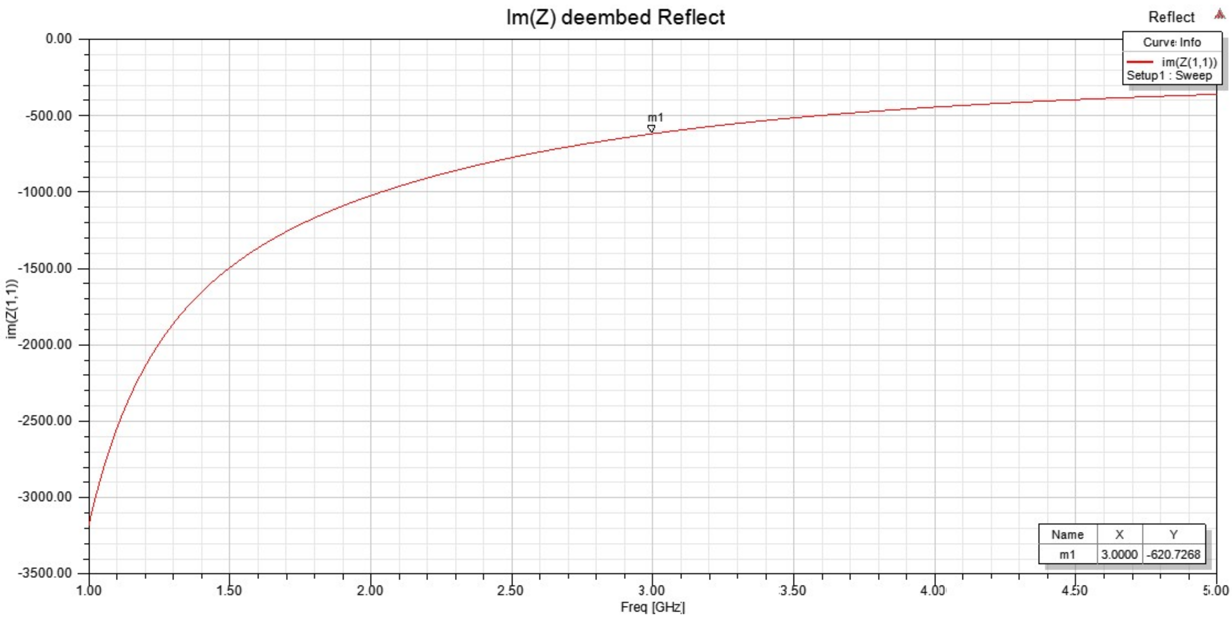
Simulation results of Reflection kit

a. Phase comparison





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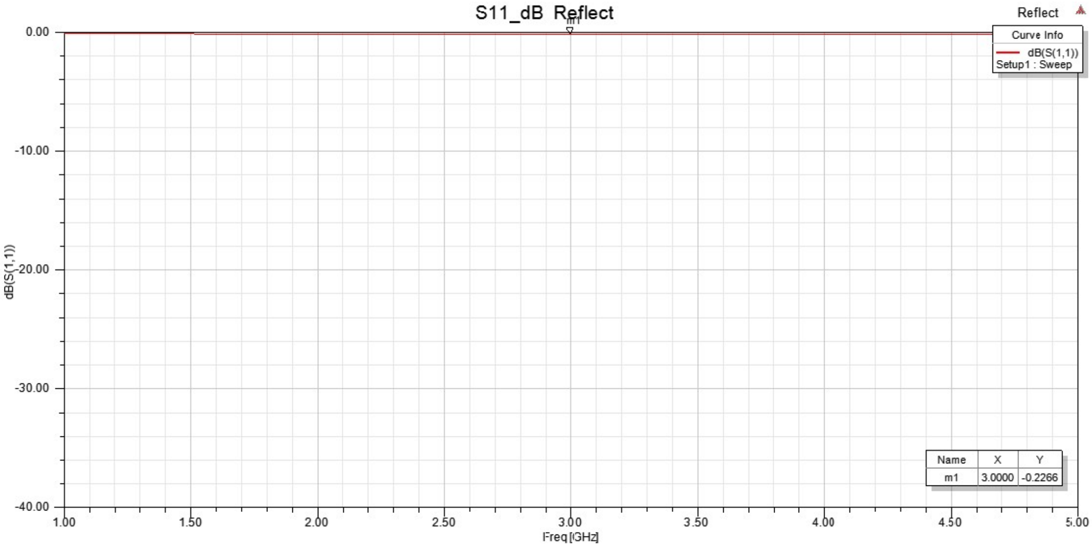
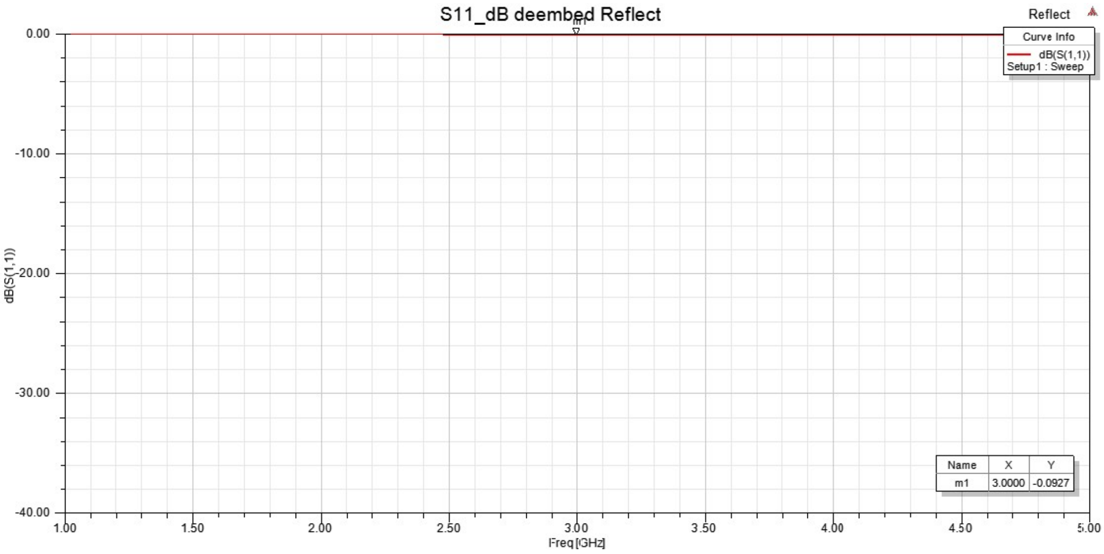
a. Magnitude comparison





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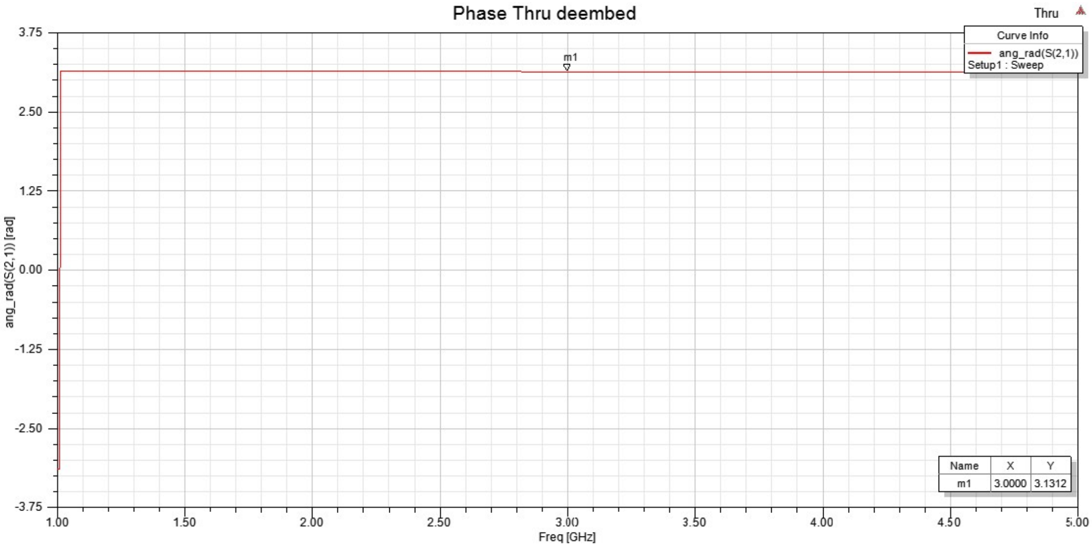
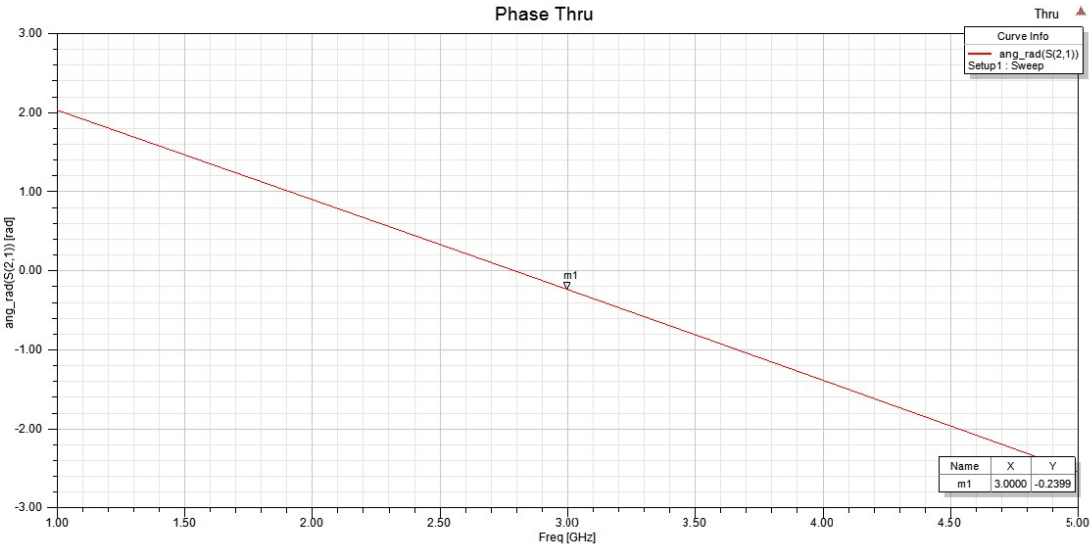
Simulation results of Line kit

a. Phase comparison





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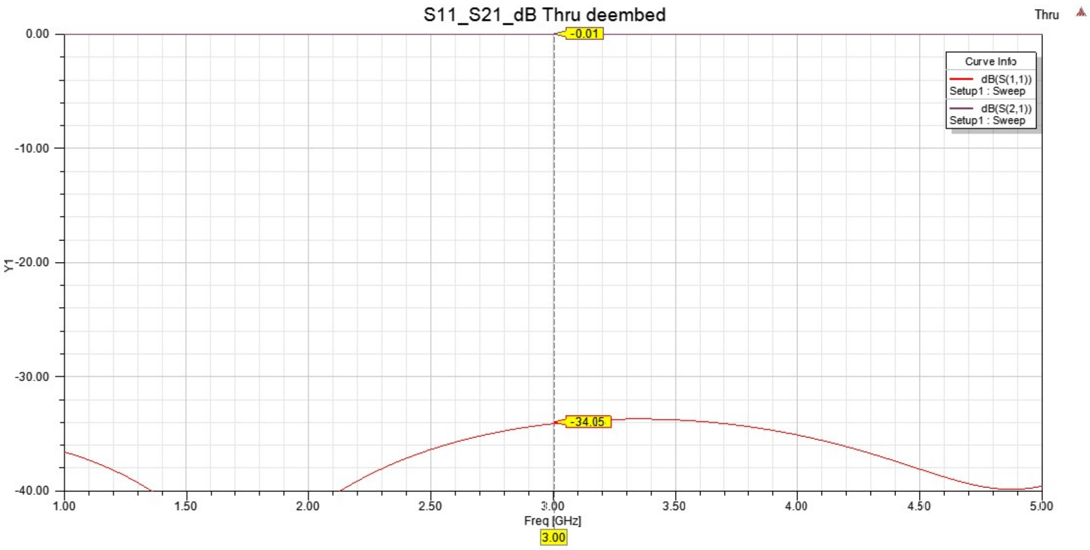
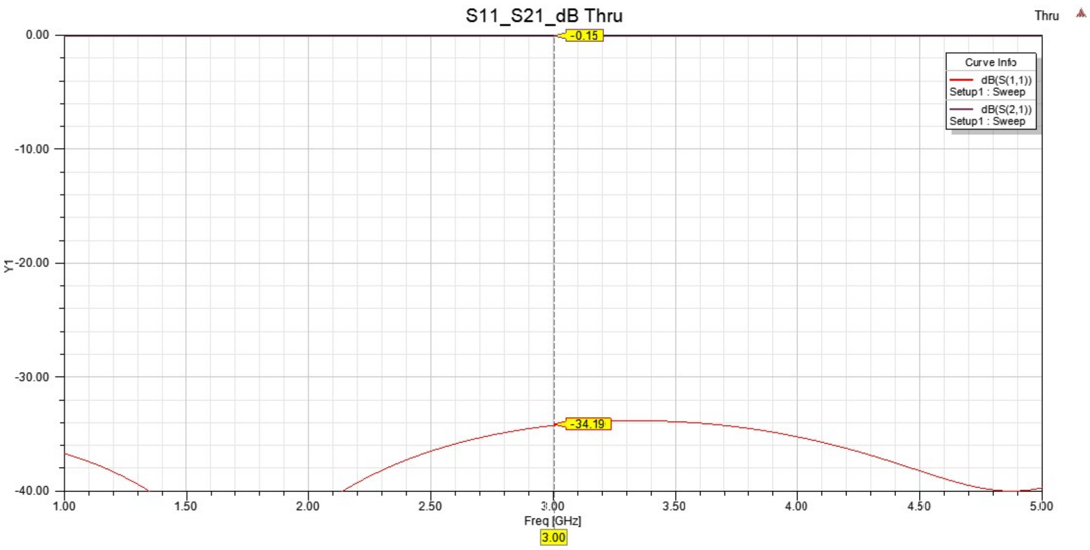
a. Magnitude comparison

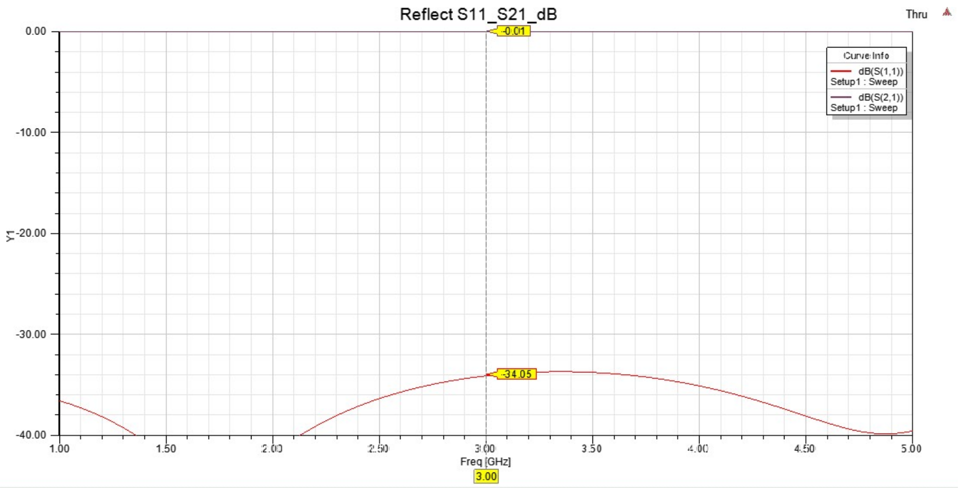




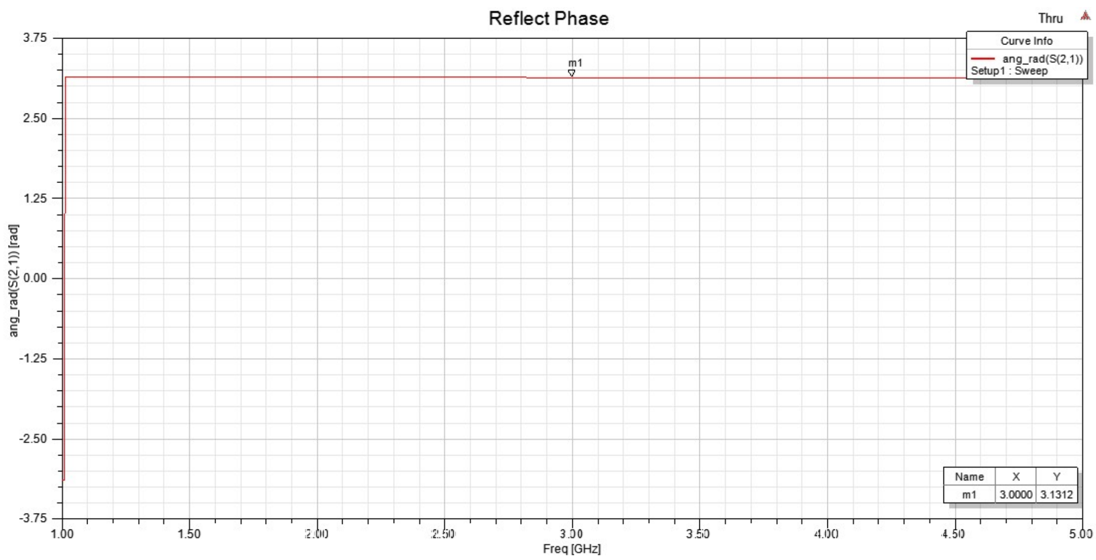
Step4:

1. Verify the Thru standard.

   S21 Magnitude is approaching to zero.



   Phase in 3GHz is approaching to 0.(or Pi)



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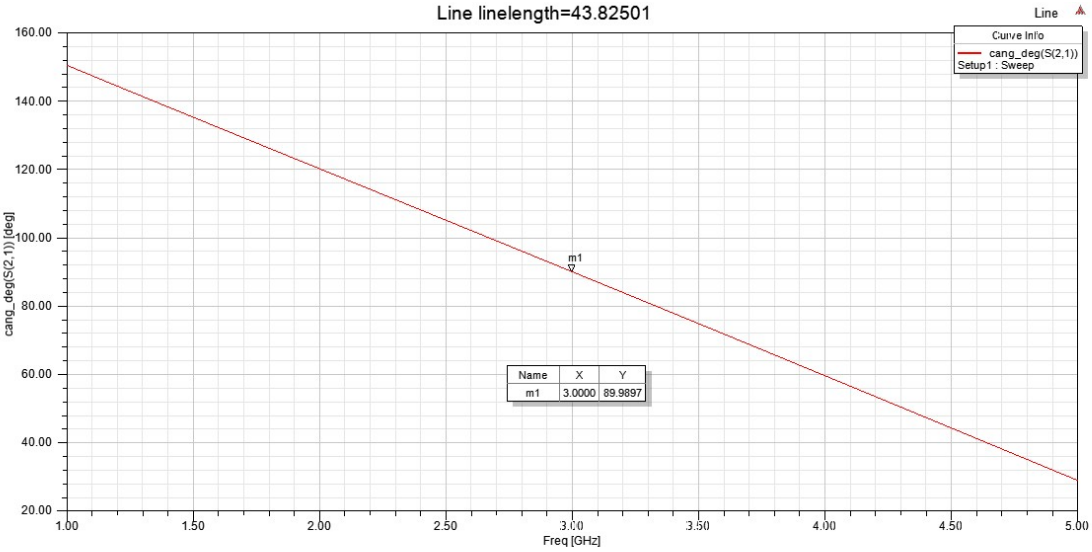
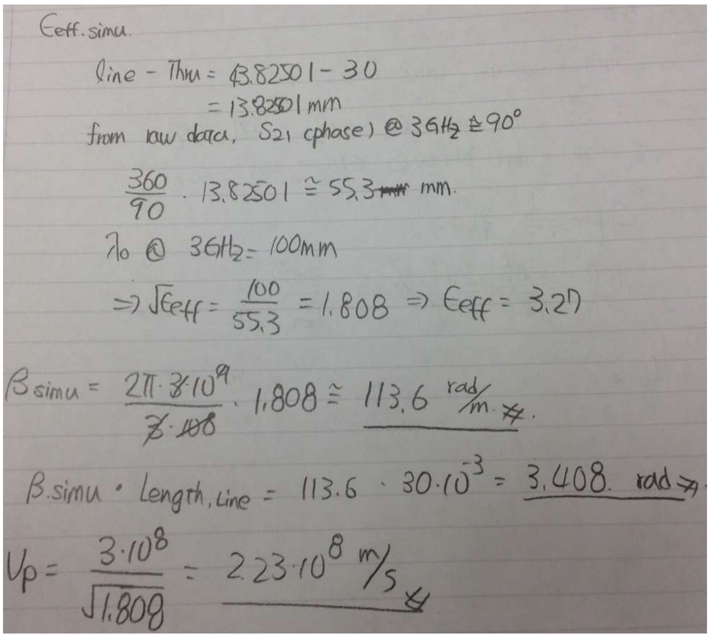
2. Verify the Line standard

   Phase approaches to 90 degree. (Line length is 43.82501 mm.)



   Calculate the phase velocity and delay of the line



ϵ_{eff}.simu.

$$\text{line} - \text{Thru} = 43.82501 - 30 = 13.82501\ \text{mm}$$

from raw data, S_{21} (phase) @ 3GHz $\triangleq 90^\circ$

$$\frac{360}{90} \cdot 13.82501 \cong 55.3\ \text{mm}.$$

$$\lambda_0\ @\ 3\text{GHz} = 100\text{mm}$$

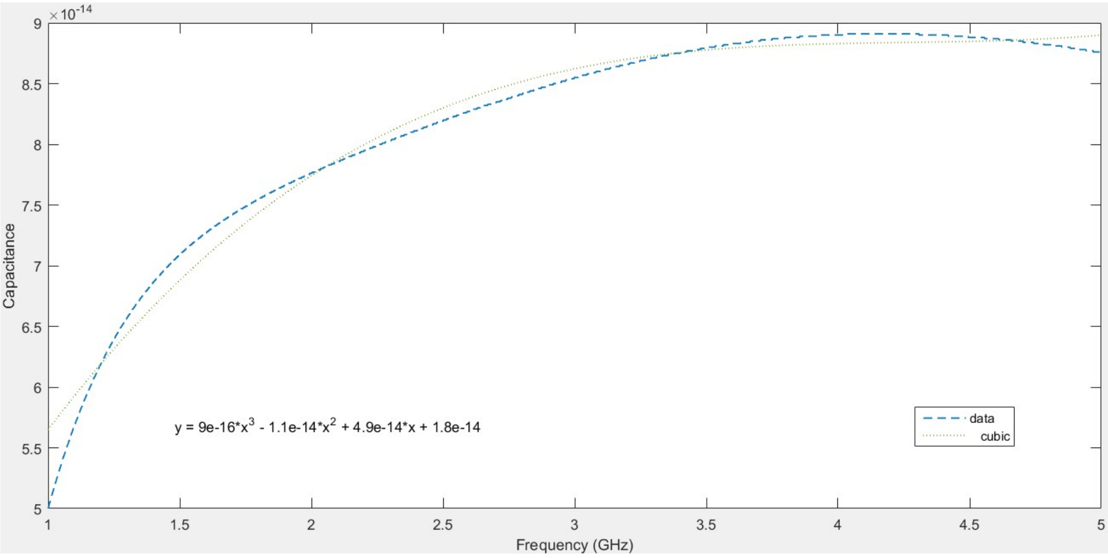
$$\Rightarrow \sqrt{\epsilon_{eff}} = \frac{100}{55.3} = 1.808 \Rightarrow \epsilon_{eff} = 3.27$$

$$\beta_{simu} = \frac{2\pi \cdot \cancel{3} \cdot 10^9}{\cancel{3} \cdot \cancel{10^8}} \cdot 1.808 \cong \underline{113.6\ \text{rad/m}}\ \#.$$

$$\beta.\text{simu} \cdot \text{Length,Line} = 113.6 \cdot 30 \cdot 10^{-3} = \underline{3.408\ \text{rad}}\ \#$$

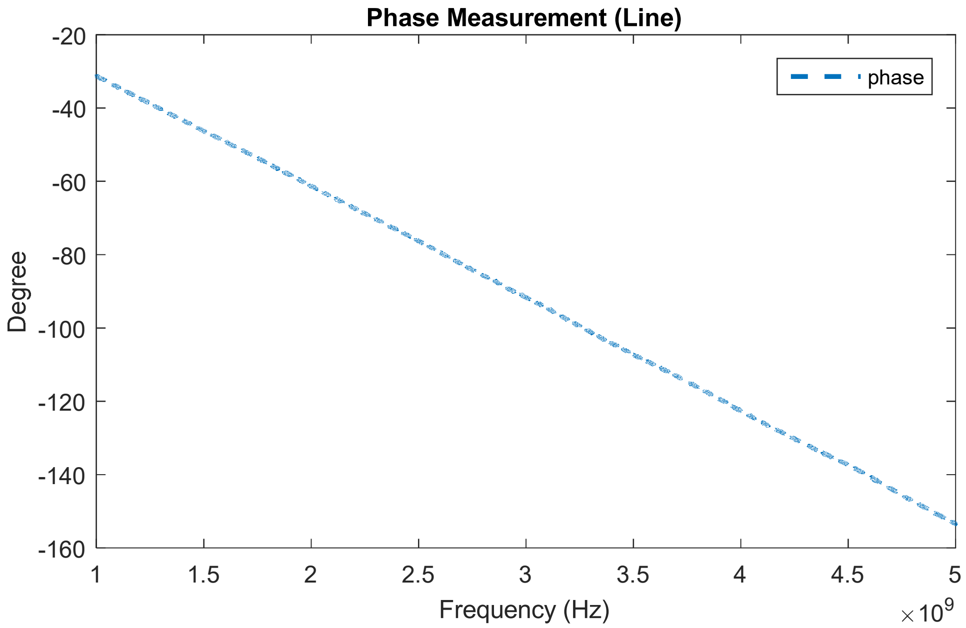
$$V_p = \frac{3 \cdot 10^8}{\sqrt{1.808}} = \underline{2.23 \cdot 10^8\ \text{m/s}}\ \#$$

3. Verify the Reflection standard



Discussion:

Line measurement:



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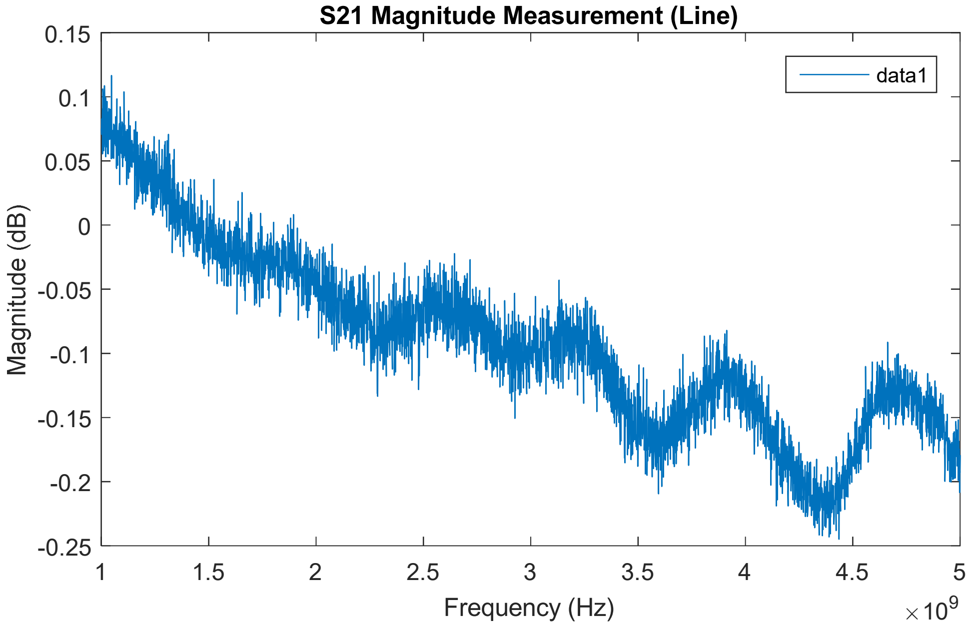
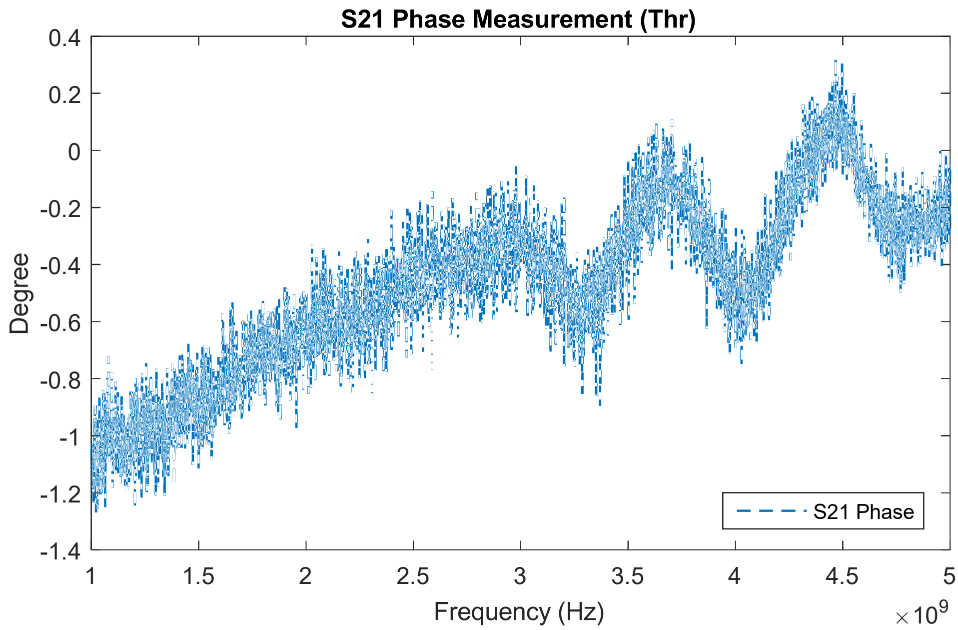
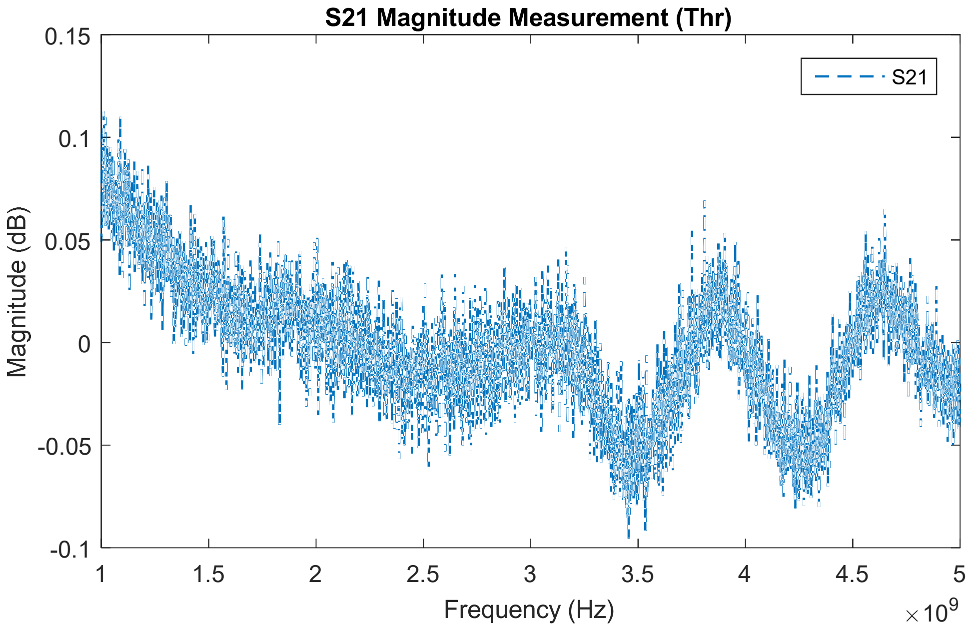




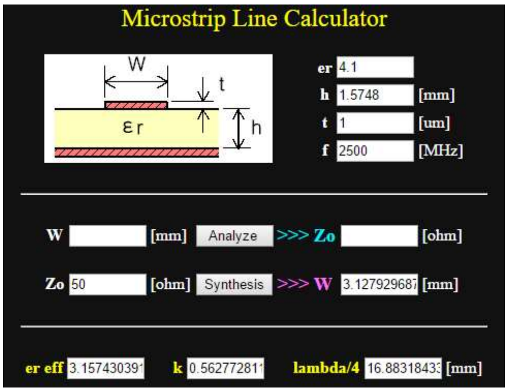


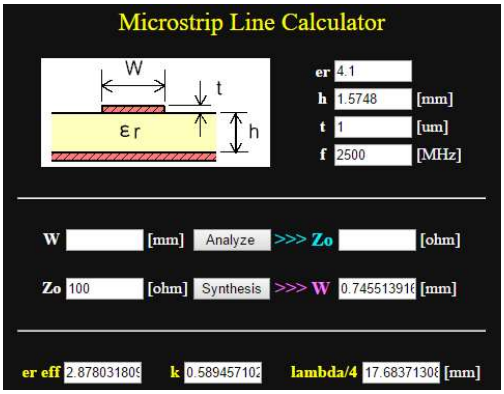
- The S parameter results from measurement are similar to the HFSS simulation results near 3 GHz. There is a slightly difference in the Phase data. The reason is the dielectric constant in our fabricate FR4 board is not 4.1 exactly and some fabrication error, like width is not the same as simulation.
- TRL calibration is like Network analyzer calibration procedure. To calibrate the experiment environment, loss, and phase to get the accurate measure results.

Task 2: Design of an RF PIN diode series switch.

Step1.

Using the Microstrip line calculator to get the physical line width of 50 ,100 ohm line and quarter wavelength distance for each impedance at 2.5 GHz.





For 50 Ohm W=3.128mm quarter wavelength distance=16.88mm

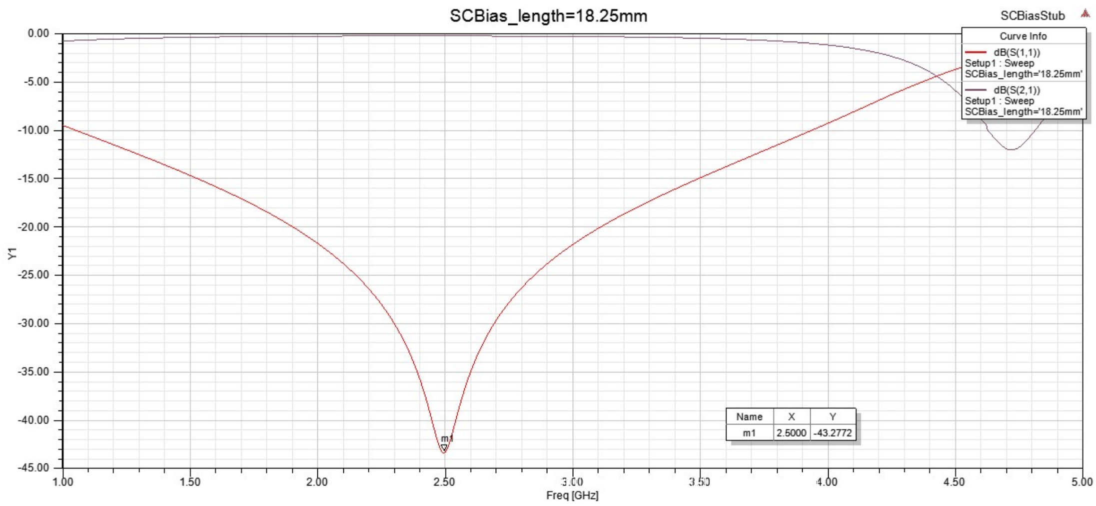
For 100 Ohm W=0.745mm quarter wavelength distance=17.68mm

- The width of 100 ohm line is smaller than 50 ohm line. The fringing effect is much more serious. Thus, the effective permittivity is smaller than the 50 ohm line and the quarter wavelength distance is longer than 50 ohm line.

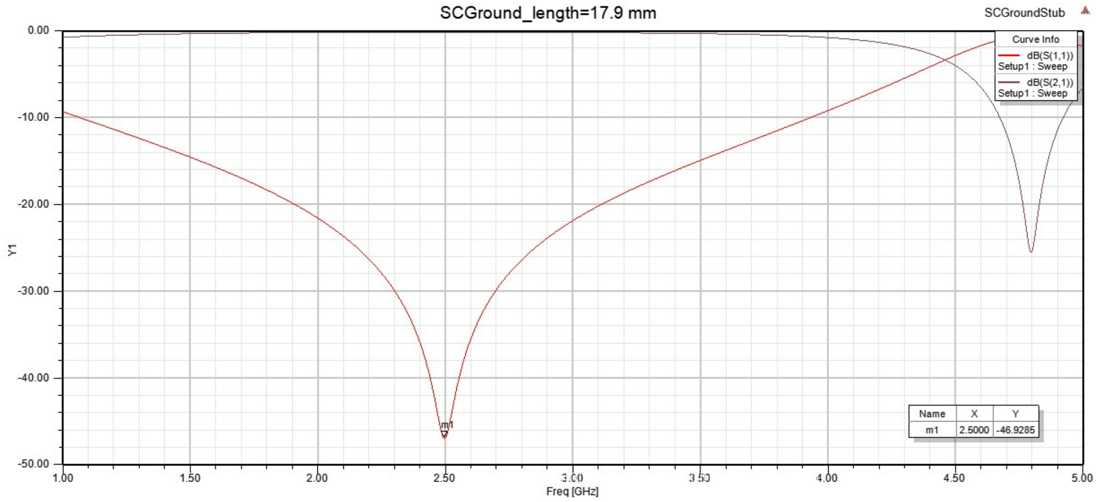
Step2.

From the Step1, knowing the quarter wavelength for 100 ohm line is 17.68 mm. But after simulation, the length (17.68mm) cannot get the best insertion loss result in both structure. Thus, altering the length to get the simulation results.

SCBias_length=18.25 mm



SCGround_length=17.9 mm

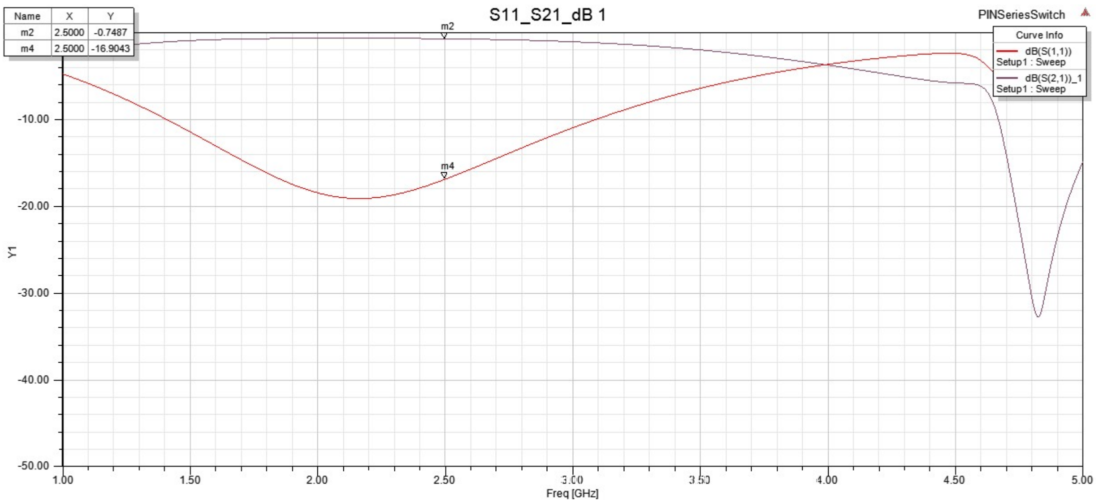


- From simulation result, the length are different between Bias stub and Ground stub. The reason is the loading for the transmission line is different. In Ground Stub, the bias tee connected to RF and DC ground using a via. The equivalent model is a series inductance to ground. In Bias Stub, the bias tee terminating with a bias capacitor in series with a via and a bias resistor with a via. This equivalent model is more complicate and different from the series inductance. By changing the length of stub, matching the different load make a S11 deep point at 2.5 GHz.

Step3.

The simulation results in different states.

Diode:ON



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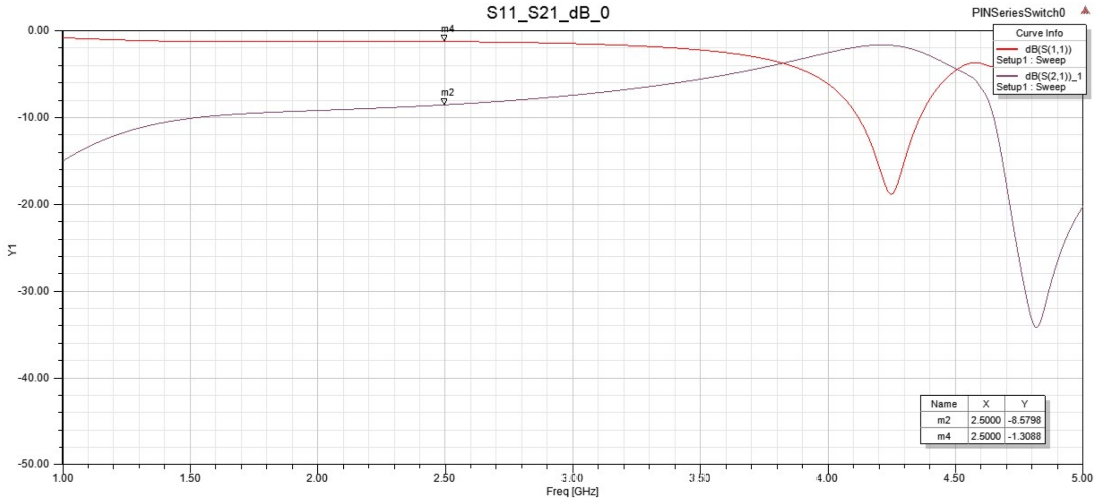
Diode:Off



- Tuning the "Sub-model" individually is much easier and time saving than tuning the whole circuit.

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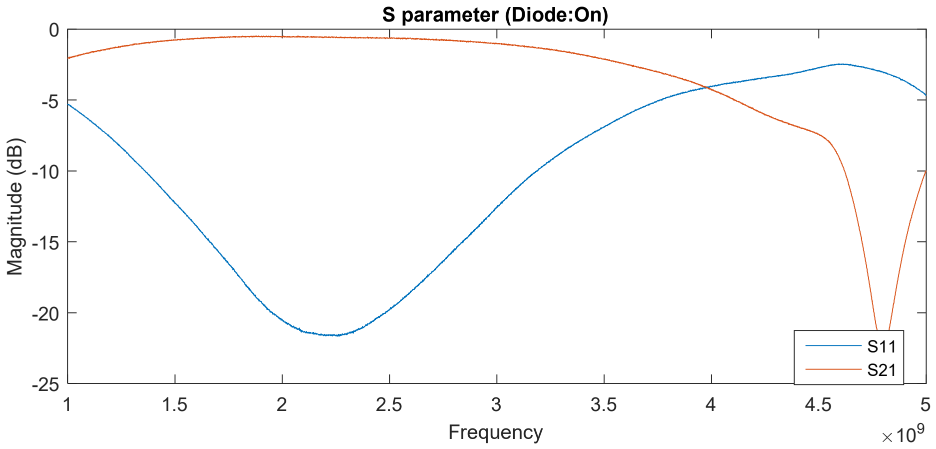
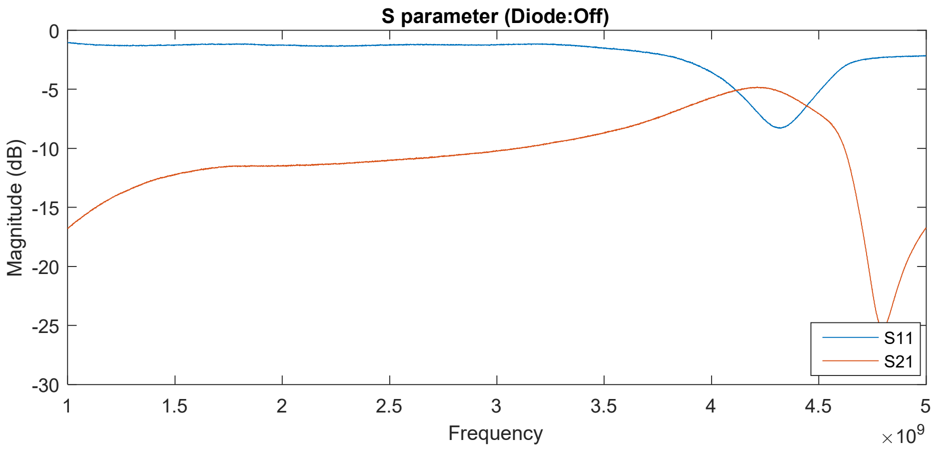
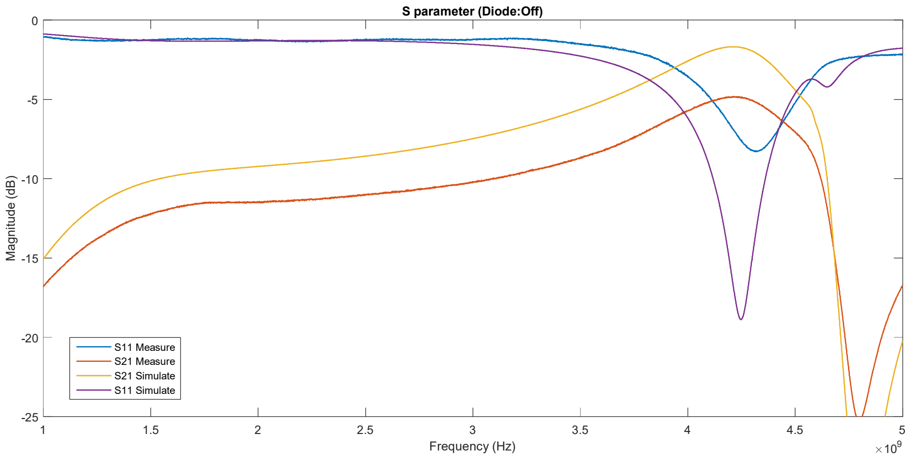
Step4.

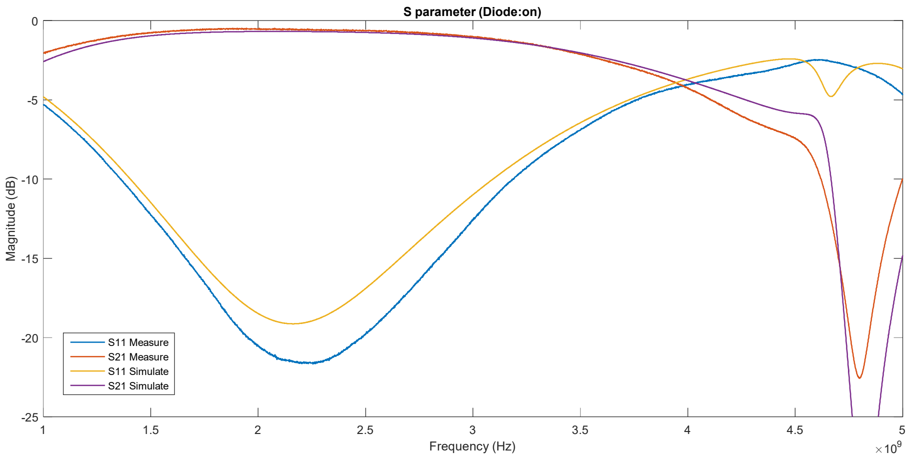
The measure results in different states.





Discussion:





- The S parameter results from measurement are similar to the HFSS simulation results near 2.5 GHz. Note the slightly difference between the measure and simulated data is mainly from the soldering elements. And TRL cannot help us to calibrate this part.