Orkun İbrahim Kök 22003656

EEE412 Assignment #3

"I completed this homework assignment independently."

The wanted circuit is created on ADS. Fig. 1 shows the circuit. The 10mA bias point is chosen.

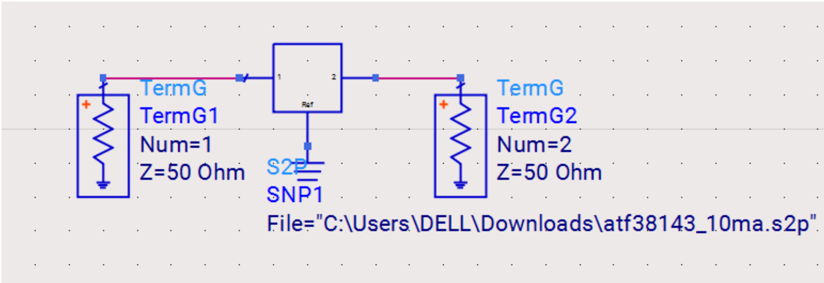

Fig. 1: Circuit Schematic

1) Fig. 2 plot shows the stability factor (K) as a function of frequency.

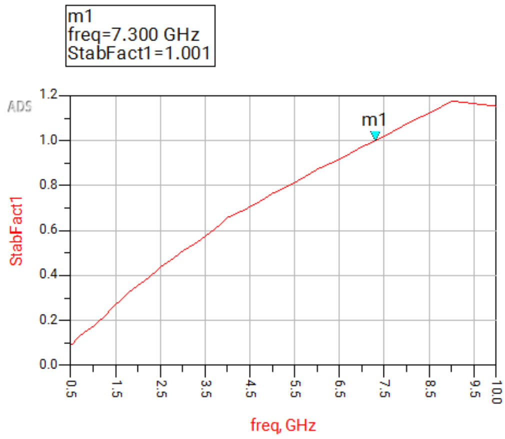

Fig. 2: Stability factor (K) plot

2) The MSG/MAG and $|S_{21}|^2$ vs. Frequency at 10mA plot is shown in Fig. 3.

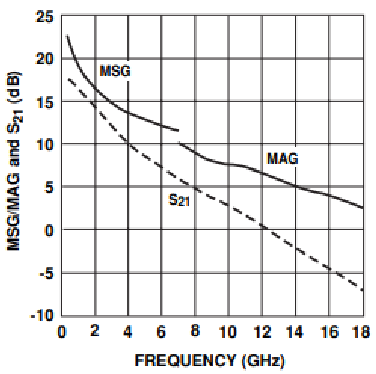

Figure 19. MSG/MAG and $|S_{21}|^2$ vs. Frequency at 2 V, 10 mA.

Fig. 3: MSG/MAG and $|S_{21}|^2$ vs. Frequency at 10mA

Fig. 4 shows the plot of the MSG/MAG vs. Frequency plot of the simulated circuit in ADS.

Fig. 4: MSG/MAG vs. Frequency for the simulated circuit

As seen from Fig. 2, K<1 until 7.3GHz, we observe MSG, and after 7.3GHz, K>1, we observe a kink in the gain curve, which is named as MAG.

3) The load and source stabiliy circles are drawn on the Smith Chart. Below figures show the source and load stability circles respectively.

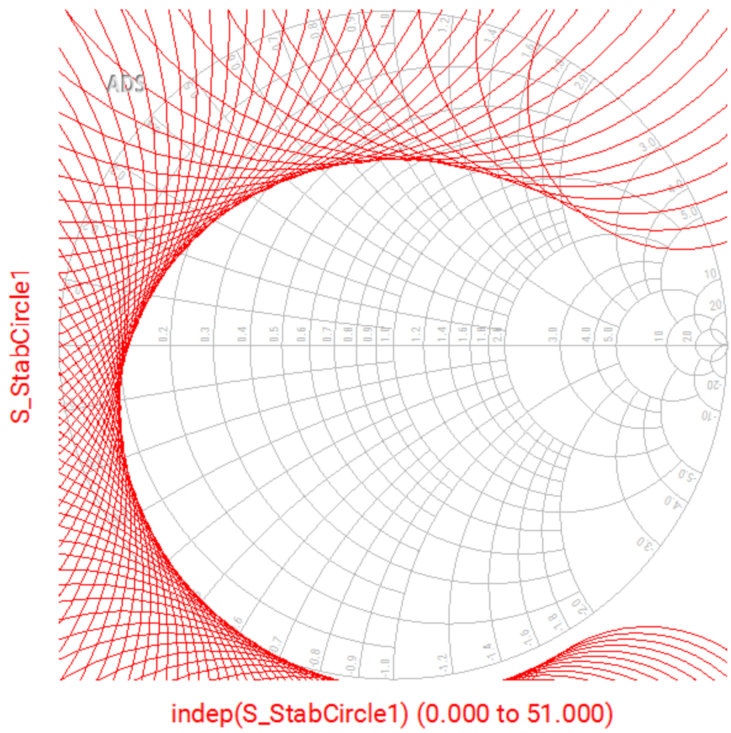

Fig. 5: Source stability circles

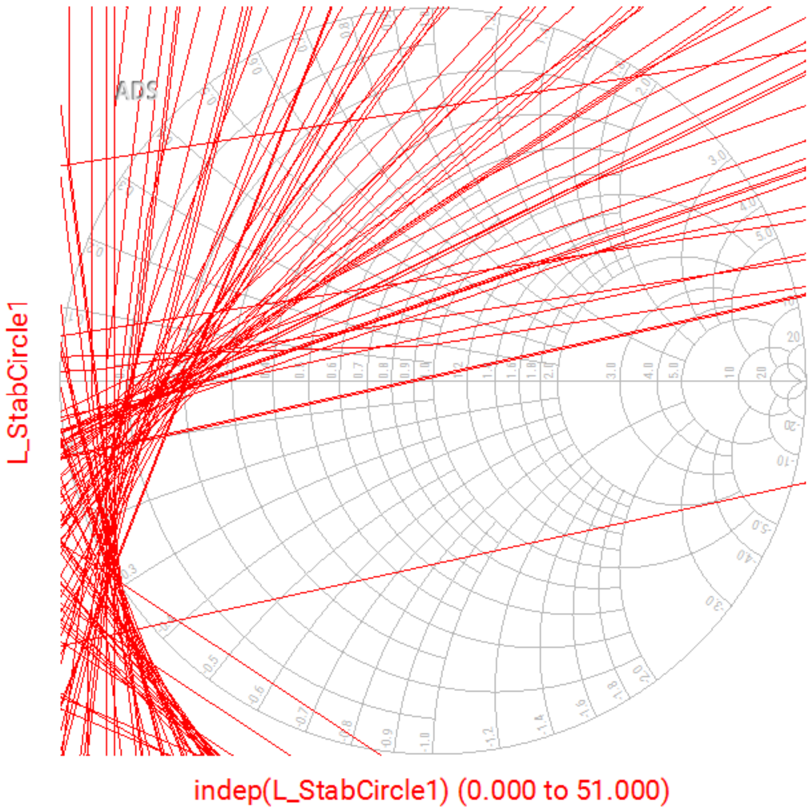

Fig. 6: Load stability circles

4) As seen from Fig. 5, center of the Smith chart is where $S_{11} = 0$. Therefore, this area is the stable region. To choose a source impedance value in the unstable region, I looked at the outside of the stable region. The chosen source impedance value is $Z_s = 0.3 + j0.7$. By using this source impedance value, S_{22} is plotted on the Smith chart. Fig. 7 shows the S_{22}.

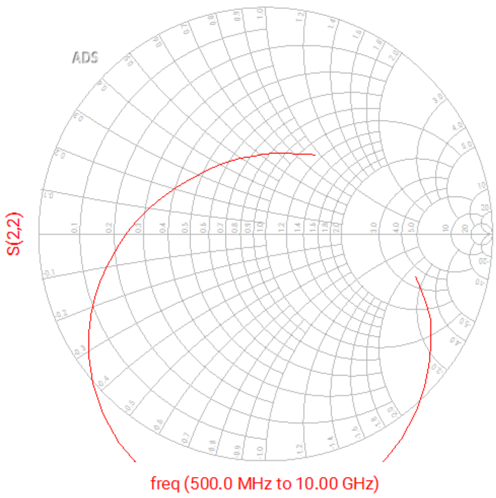

Fig. 7: S_{22} plotted on the unit Smith chart

As seen from Fig. 7, S_{22} goes outside of the unit Smith chart, which was expected due to unstability.

5) In this part, appropriate resistive networks are added into both input and output. Fig. 7 shows the source and load stability circles on the unity Smith chart.

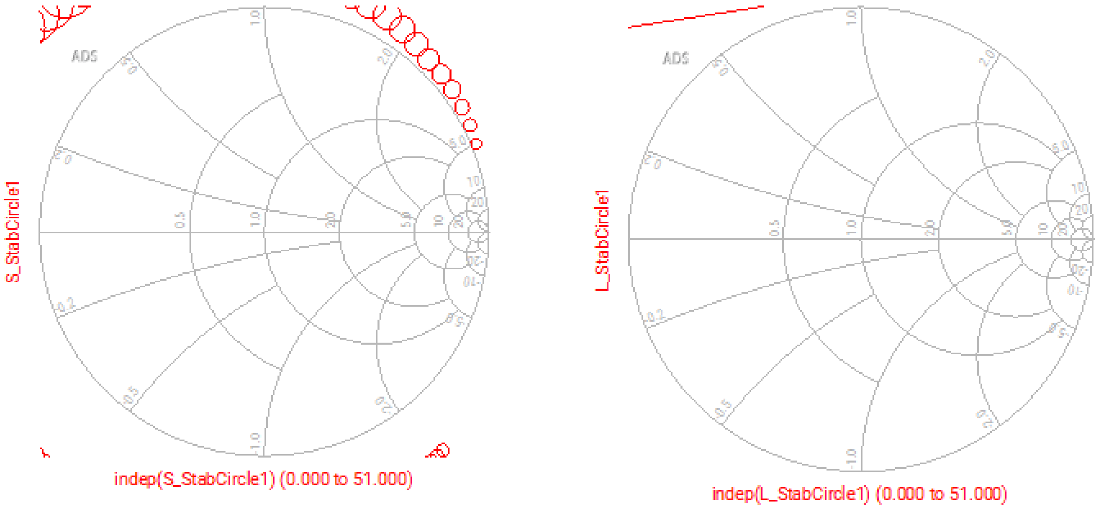

Fig. 8: Source and load stability circles on the unity Smith chart

As seen from the above figure, the circuit is now uncoditianlly stable, because the stability circles are outside of the unity Smith chart, which makes the circuit stable no matter what the frequency value is. By tuning, the resistor values are found. Fig. 9 shows the new circuit schematic.

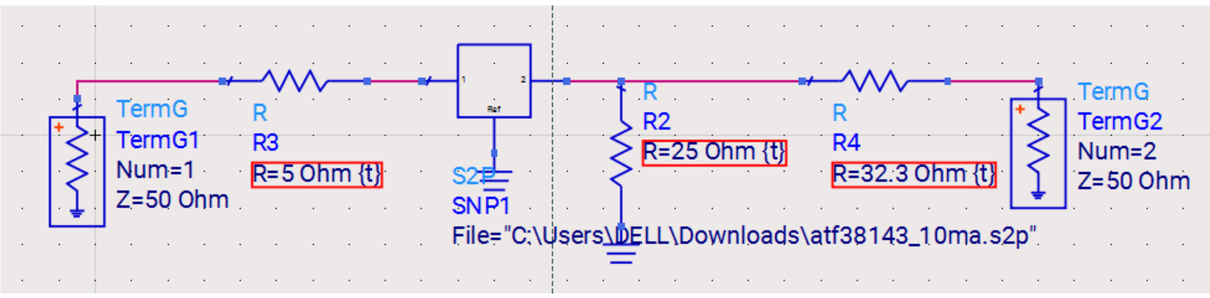

Fig. 9: New circuit schematic with tuned resistive networks

The stability factor (K) plot is given in the figure below. The marker is placed at 1GHz, where the stability factor (K) value is measured as 1.282, which is bigger than one and close to unity. The purpose for choosing this frequency is to achieve the highest gain.

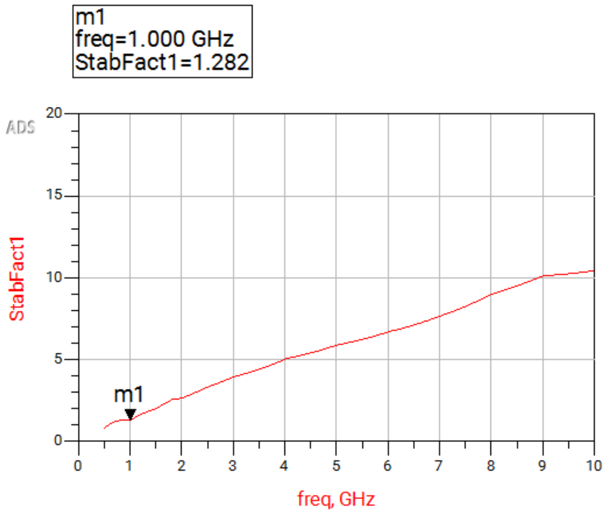

Fig. 10: Stability factor plot

The corresponding gain plot is given in Fig. 11

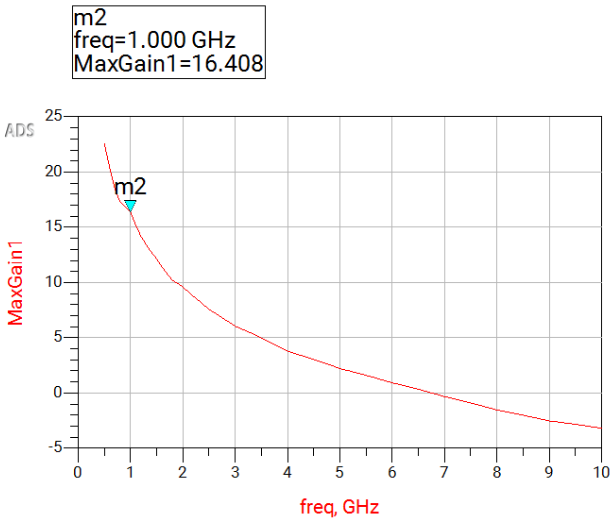

Fig. 11: Max gain plot

As seen from Fig. 11, at 1GHz, there is a kink, which is the connection between MSG and MAG. The measured gain of the circuit is 16.4 dB at 1GHz.

6) At 1GHz, the available gain circle is plotted on the Smith chart. The dot (m3 marker) represents the optimal source impedance value, and the circle (m4 marker) represents the possible source impedance values at 1GHz with a 0.1dB gain reduction. Fig. 12 shows these markers.

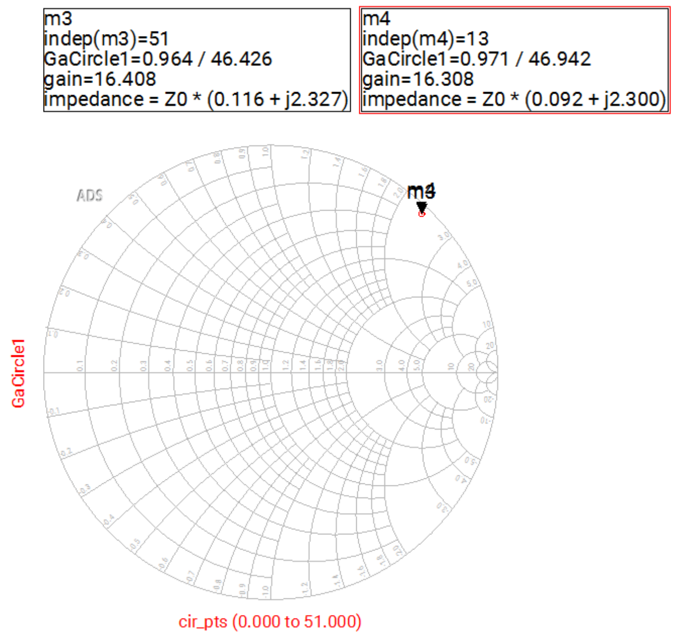

Fig. 12: Optimal source impedance value (m3 marker) and possible source impedance value (m4 marker) with 0.1dB gain reduction

7) An input matching network is inserted between the input port and the stabilized transistor. In the input, a series L, shunt L, and again a series L is used as a matching network. The values of the inductors are first calculated roughly using the Smith chart, then by using the tuning feature of the ADS, final values are obtained.

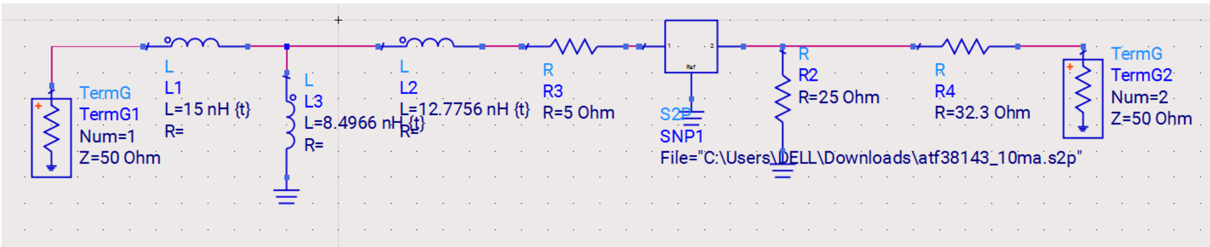

Fig. 13: New schematic with the input matching network present

As seen from Fig. 14, the dot is now at the center of the Smith chart.

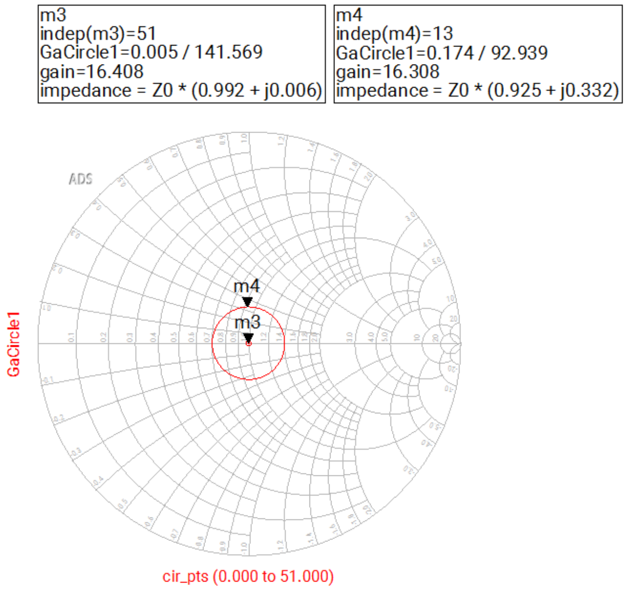

Fig. 14: Dot is at the center of the Smith chart

8) Now, the optimal load impedance value is measured. The dot (m5 marker) in Fig. 15 represents the optimal load impedance value, and the circle (m6 marker) represent the optimal load impedance value with 0.2dB gain reduction.

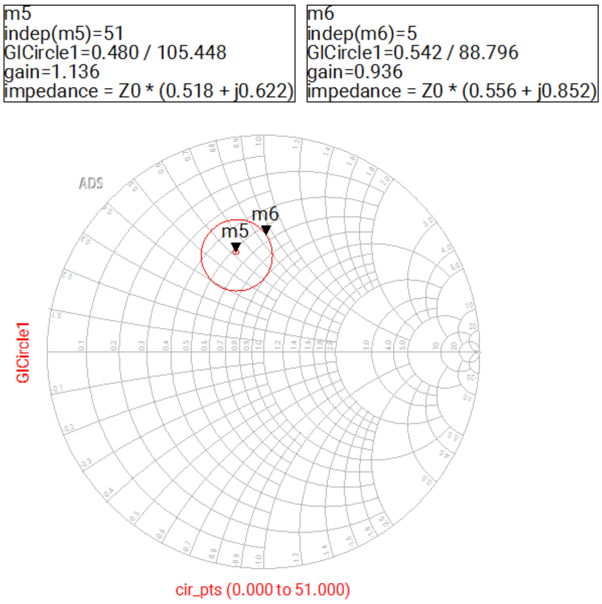

Fig. 15: Optimal load impedance value

9) At the output, a shunt L and a series C matching network is used. The goal here is again changing the place of the dot, which is present on Fig. 15, to become at the center of the Smith chart. Again, the values of the lossless components are first found roguhly by Smith chart, then using the tuning feature of the ADS, final values are obtained. Fig. 16 shows the final version of the schematic.

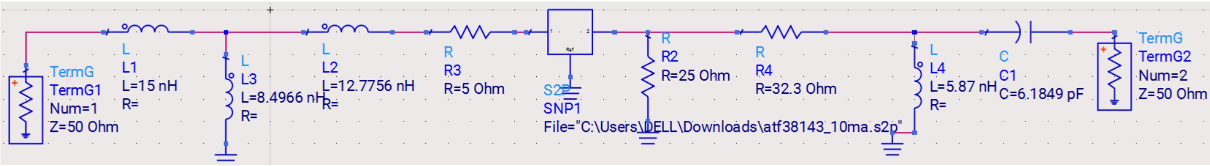

Fig. 16: Final version of the circuit with input and output matching networks present

Fig. 17 shows the place of the dot, where is at the center of the Smith chart.

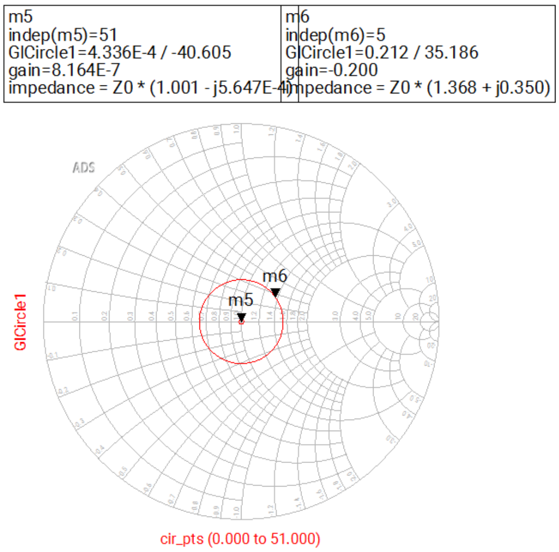

Fig. 17: The dot is at the center of the Smith chart

10) The S_{21} is plotted in dB. Fig. 18 illustrates the corresponding plot.

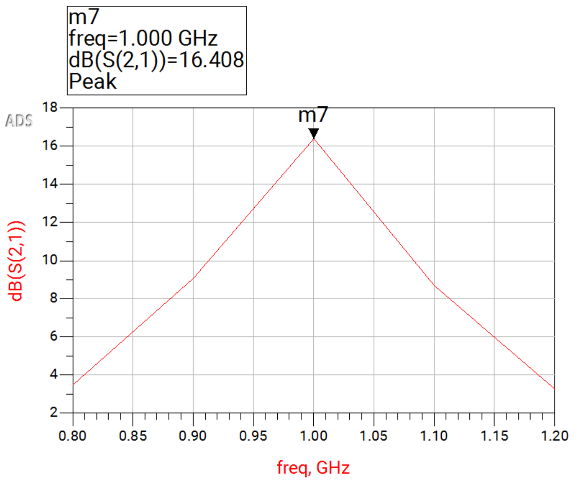

Fig. 18: S_{21} plot

The G_T equation is given below:

$$\frac{1-|\Gamma_S|^2}{|1-s_{11}'\Gamma_S|^2}|s_{21}|^2\frac{1-|\Gamma_L|^2}{|1-s_{22}\Gamma_L|^2}$$

When we conjugately match the output, that is to say:

$$s_{22}=\Gamma_L{}^*$$

G_T, "Transducer Power Gain" definition becomes G_A definition, which is" Available Gain". So we get the maximum gain at the desired frequency, which is 1GHz. In Fig. 11, the maximum gain is measured as 16.408dB. Whereas now, looking at the Fig. 18, again the maximum gain is measured as 16.408. Which means that the matching networks are working, the requirement is satisfied.

11) This part asks for the frequency band which is $|S_{11}|$ and $|S_{22}|$ are less than -12dB individually. Fig. 19 shows the frequency points indicationg with markers.

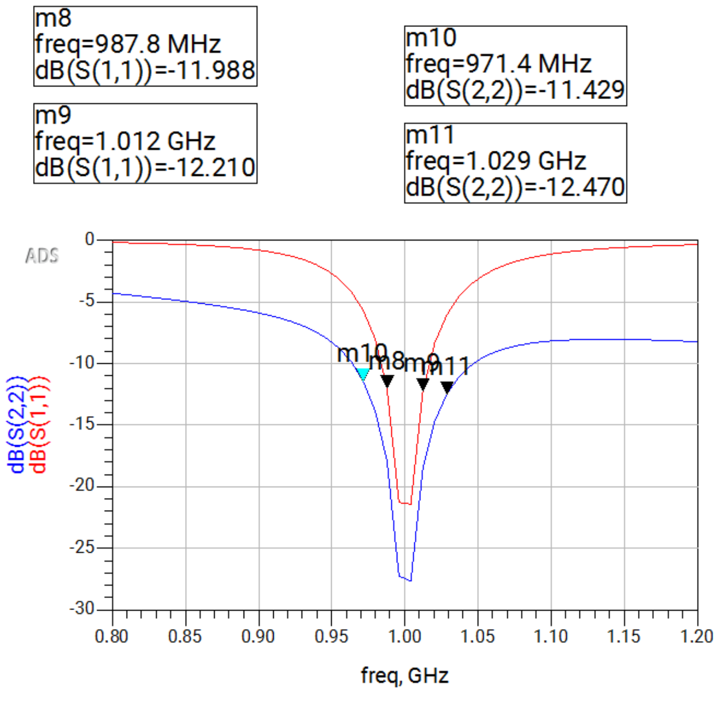

Fig. 19: S_{11} and S_{22} plots

As seen from Fig. 19, S_{11} is less than -12dB starting from around 990MHz, and stops around 1.01GHz. Whereas, S_{22} is less than -12dB starting from around 980MHz, and stops around 1.03GHz.

12) Noise analysis is done for our circuit in ADS. Fig. 20 depicts the nf2 plot, which is the noise figure at the output port, and Fig. 21 shows the NFmin plot, which is the minimum noise figure than can be achieved.

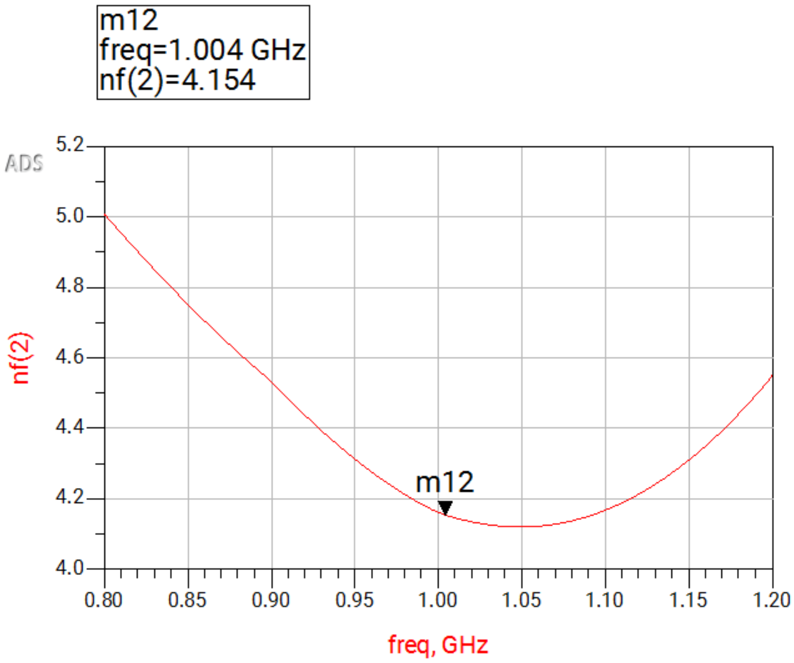

Fig. 20: Noise figure f the circuit at the output port

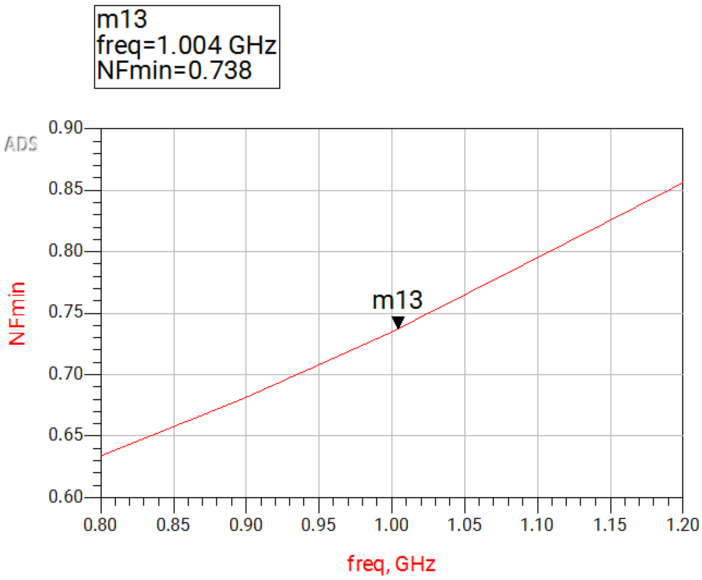

Fig. 21: Minimum noise figure that can be achieved

13) Noise circle is shown on the same Smith chart with the Ga and Gl circles. Fig. 22 shows the Smith chart.

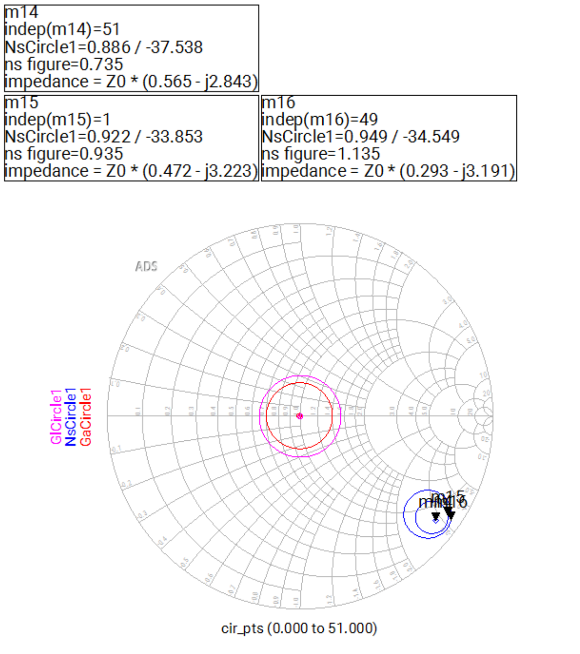

Fig. 22: Noise circle

Here, the m14 marker shows the NFmin, m15 marker shows the NFmin + 0.2dB, and m16 marker shows the NFmin + 0.4dB.

14) As wanted, the NFmin + 0.2dB circle is touching the center of the Smith chart by tuning the input matching network. And tuning the output matching network, the Ga and Gl circles are recentered.

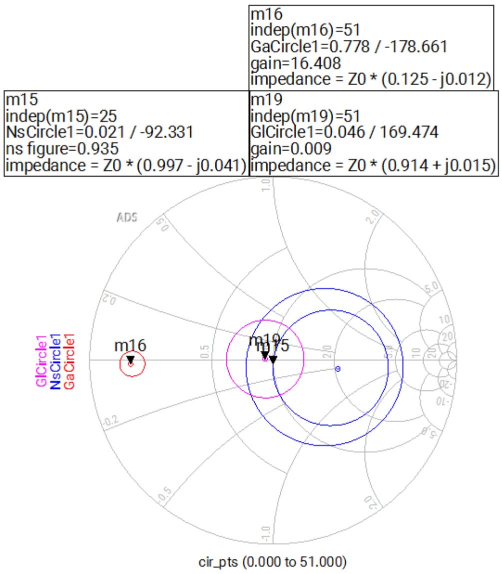

Fig. 23: Ga, Gl, and noise figure circles

M15 marker shows that the 0.2dB circle is touching to the center of the Smith chart. M16 marker shows that the center of Ga and Gl circles are same by tuning. M19 marker shows that Glcircle is retuned so that it is recentered at the center of the Smith chart. The best value achieved is near the center which is $0.914Z_0$. Fig. 24 shows the new circuit schematic with changed inductance and capacitance values.

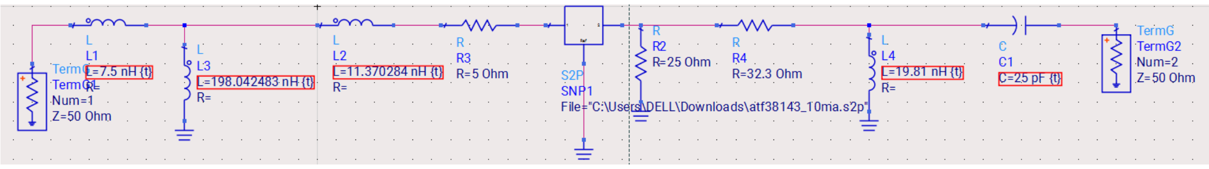

Fig. 24: New shcematic of the circuit tuned for noise optimisation

15) In this part, S_{21}, S_{11}, and S_{22} are plotted in dB. Additionally, noise figure and Fmin are plotted separately.

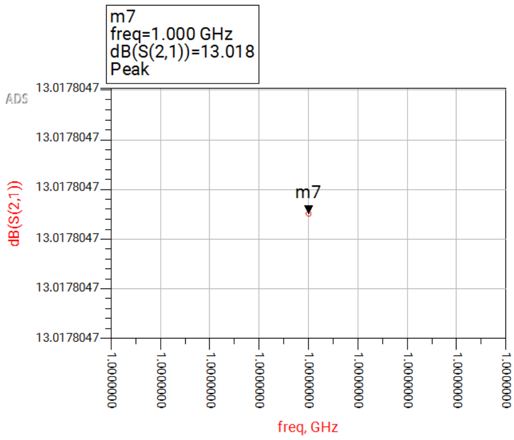

Fig. 25: S_{21} plot

As seen from Fig. 25, the new gain of the circuit is reduced to 13.018dB, whereas before it was 16.408dB. Noise figure optimization is the cause of this reduction in gain, because of the changes done in the input matching network.

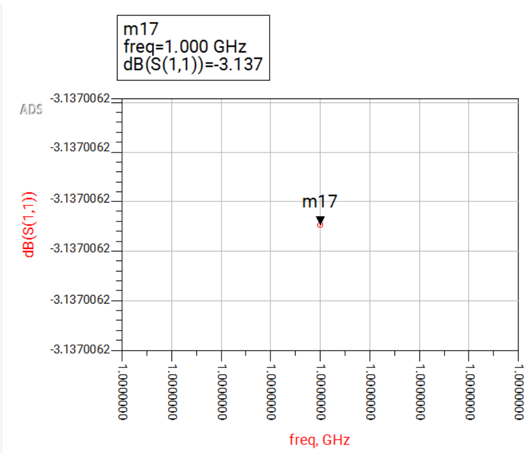

Fig. 26: S_{11} plot

Fig. 26 depicts the plot of S_{11}. Because it is far away from the Smith chart right now, it is not less than -12dB.Fig. 27 shows the plot of S_{22}.

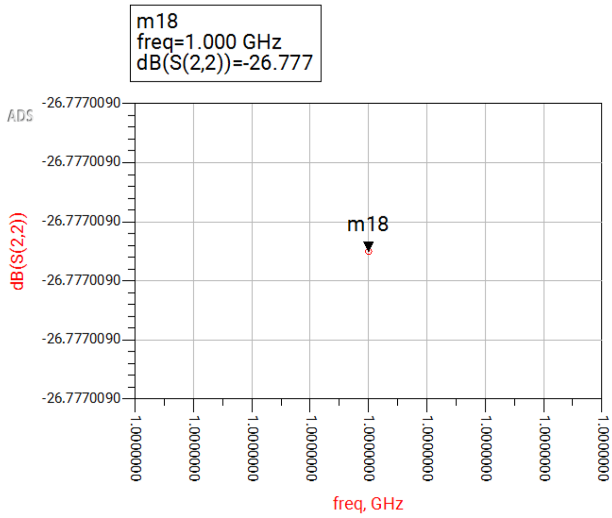

Fig. 27: S_{22} plot

As expected, we retuned the Glcircle to make its center recentered at the center of the Smith chart. The value of S_{22} is measured as -26.77, which is less than 12dB.

The noise figure of the circuit has reduces substantially. Before it was measured as 4.154, as depicted in Fig. 20. Now, the noise figure is measured as 0.936.

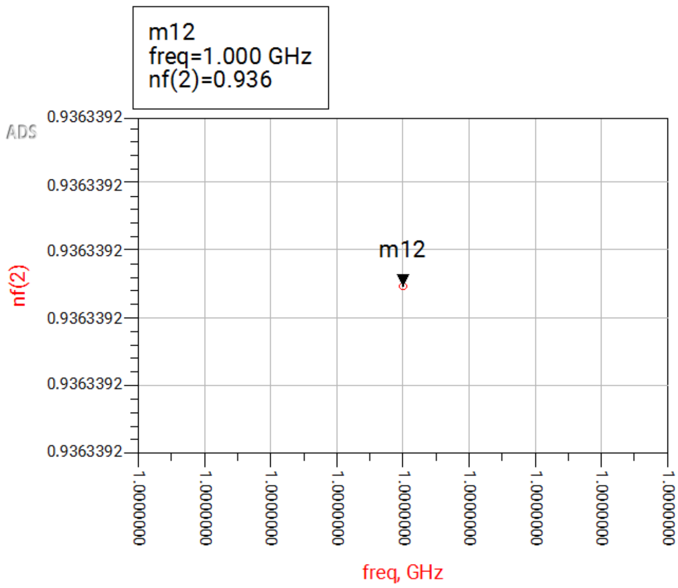

Fig. 28: Noise figure of the circuit

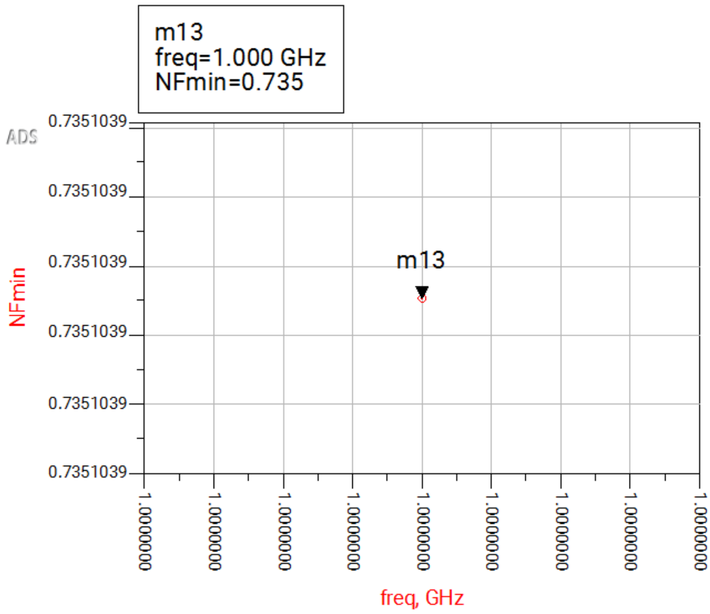

Fig. 29: NFmin of the circuit

Fmin of the circuit is measured as 0.735. Regarding this value, the circuit has achieved a good noise figure, which is close to the best achievable noise figure.

16) An inductor is placed between source and ground of the transistor. With this inductor, it is achieved to make Ga circle closer to noise figure. By tuning feature of the ADS, the following resutls are obtained. Inıtially, Fig. 30 shows that the placement of the circles.

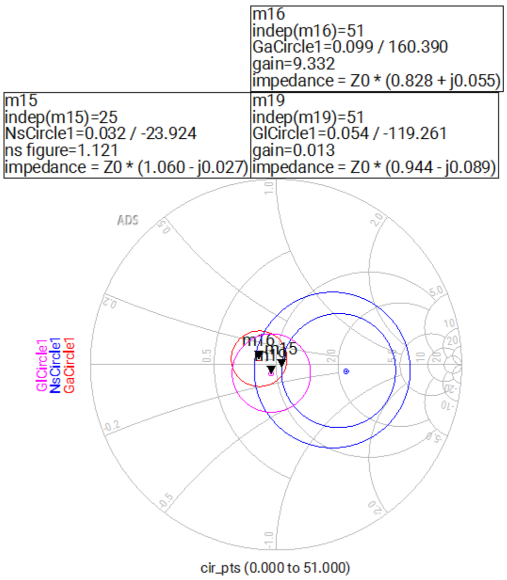

Fig. 30: Ga, Gl, and noise figure circles

As seen from Fig. 30, the circles are now close to each other, which is wanted.

Fig. 31 shows the achievable minimum noise figure. It is measured as 0.921, whereas earlier it was measured as 0.738

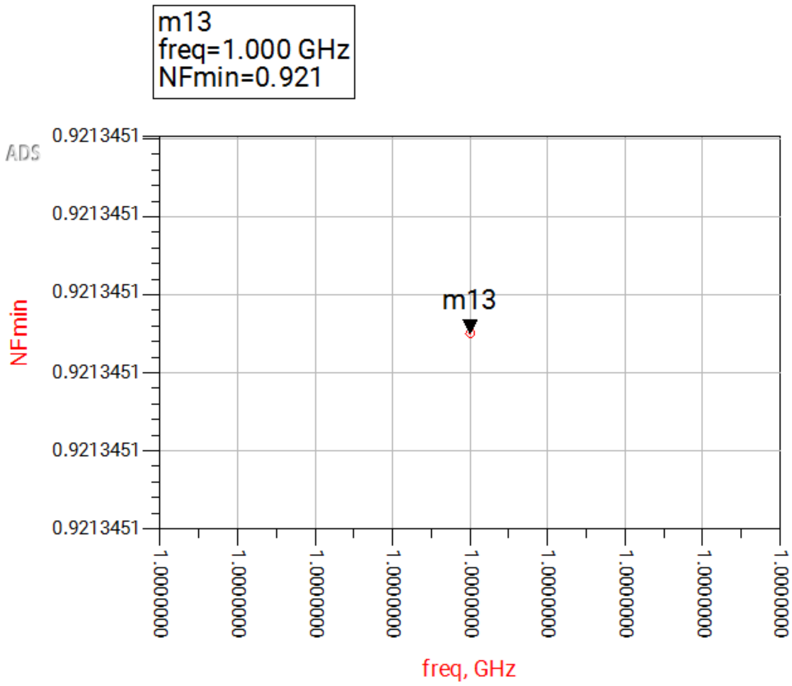

Fig. 31: Fmin of the circuit

Below figure shows the noise figure of the circuit. It was measured as 1.156, which is close to the Fmin value. Previously, it was measıured as 0.936.

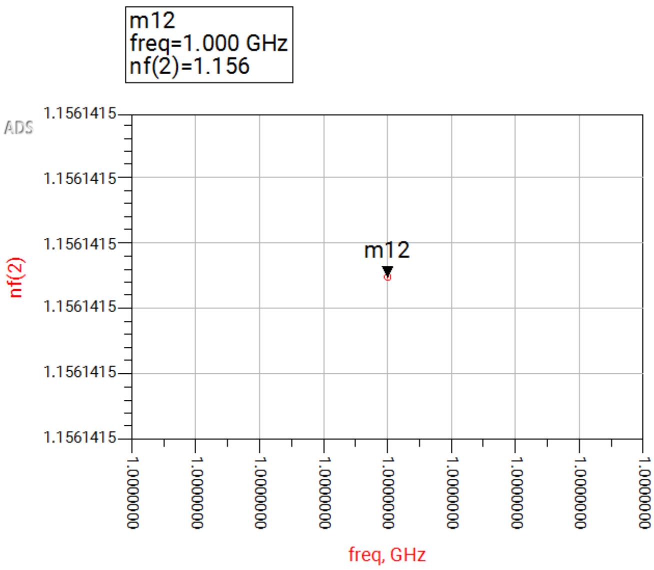

Fig. 32: Noise figure of the circuit

S_{11} in dB is given in the figure below. Because we made Ga circle close to center of the Smith chart, now the value of S_{11} is less than -12dB, which is measured as -19.72dB. Previously it was measured as -3.137dB.

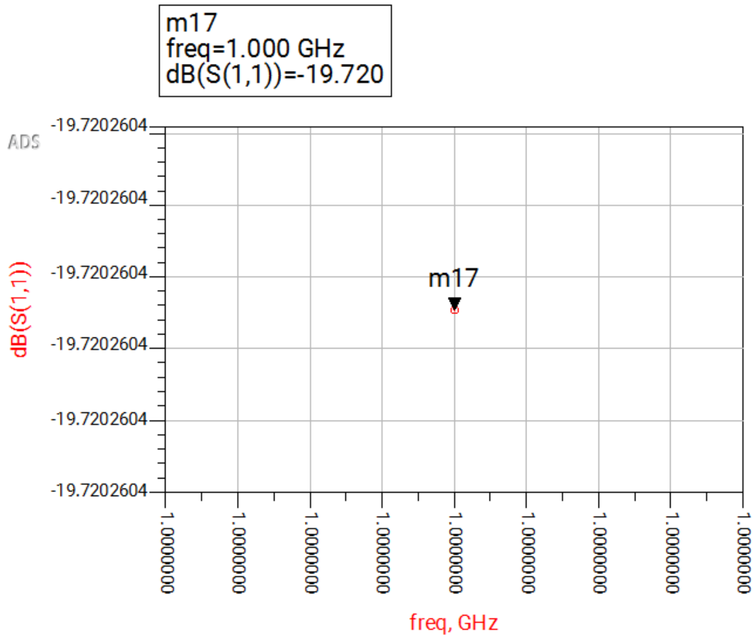

Fig. 33: S_{11} plot

Fig. 34 shows the S_{22} plot in dB. The measured value is -25.331dB, which is less than -12dB. Earlier it was measured as -26.777dB. Every result is seem reasonable right now.

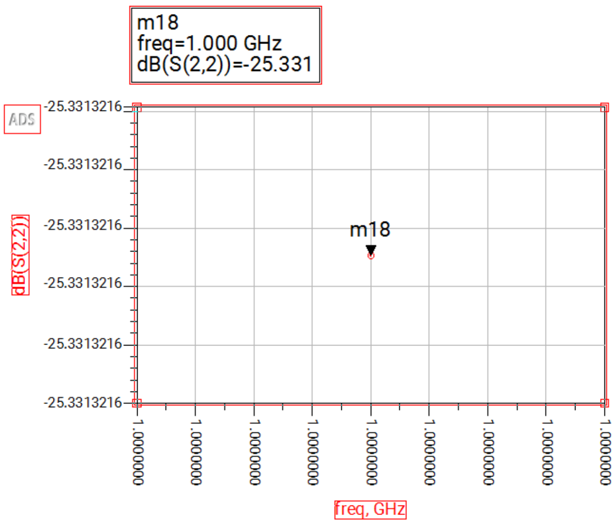

Fig. 34: S_{22} plot

S_{21} plot is given in Fig. 35. It was measured as 9.277dB, whereas it wa measured as 13.018dB.

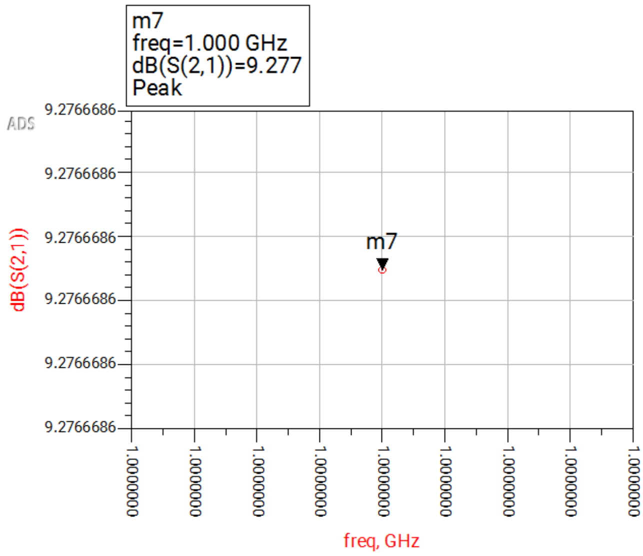

Fig. 35: S_{21} plot

Lastly for the stability check of the circuit, source and load stability circles are plotted from 0.5GHz to 10GHz. Fig. 36 shows the plots.

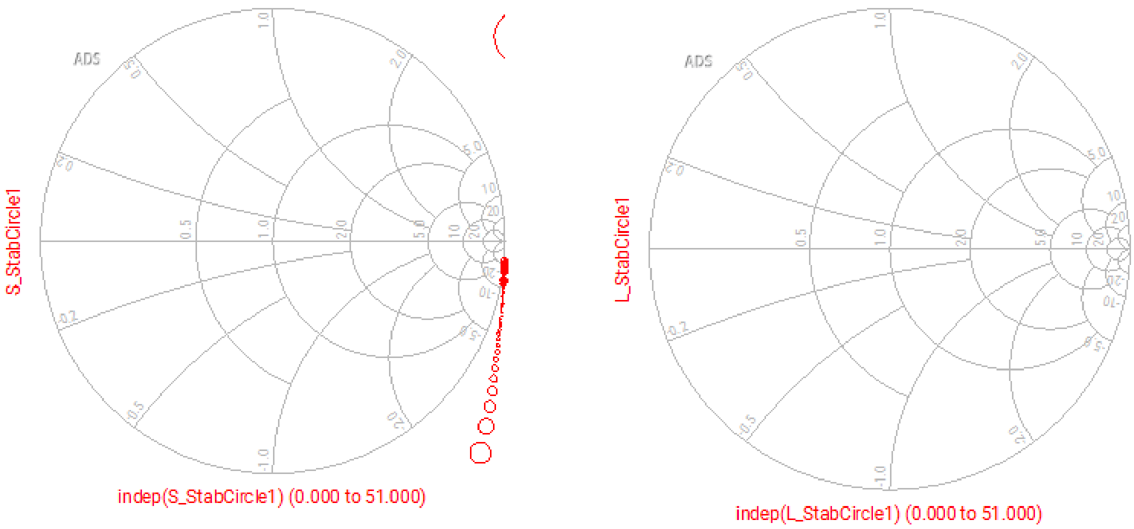

Fig. 36: Source (left) and Load (right) stability circles

As seen from the above figure, the circles are not inside unity Smith chart, which shows the circuit is unconditionally stable through all frequencies.

The stability factor and max gain curves are shown in Fig. 37.

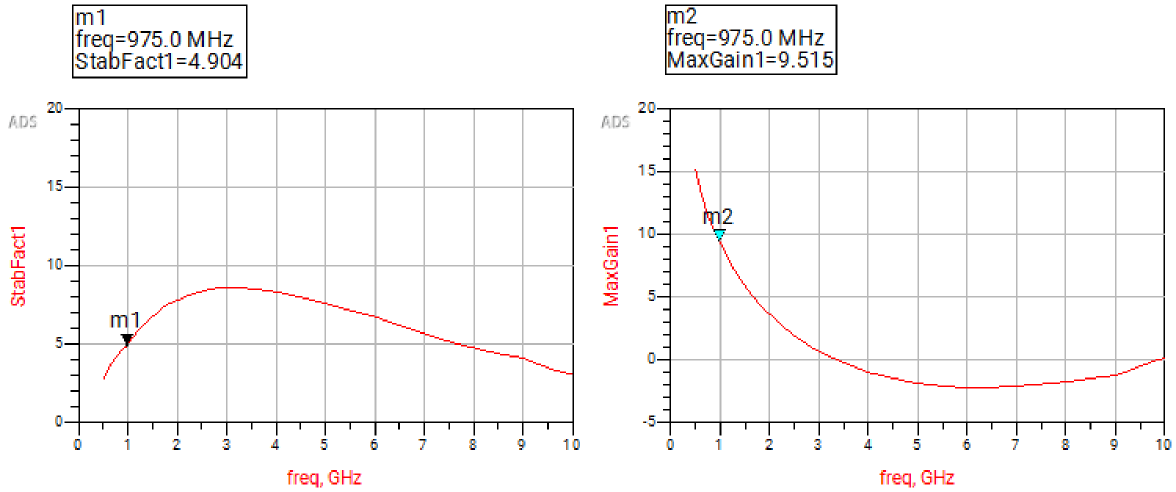

Fig. 37: Stability factor (K) and Max gain plots