Planar Loop Antenna with Matching Network

Sefa Kayraklık

***Abstract*—The impedance matching to 50Ω of a planar circular loop antenna, which works at a resonance frequency of 2.4GHz, is analyzed by the means of the simulation tool of Ansys High Frequency Structure Simulator (HFSS). Since the antenna cannot be self-resonant at 2.4GHz, a matching network consisting of a capacitor and an inductance can be deployed to ensure that the antenna operates at the specified frequency.**

***Index Terms*—Planar Circular Loop Antenna, HFSS, Impedance matching**

I. Introduction

As concluded in the previous report, a circular loop antenna could not be matched by altering its dimensions since in the region of its self-resonance, the antenna has an input impedance of almost 150Ω. Therefore, in order to match its input impedance to 50Ω, a matching network consisting of a capacitor and an inductor is needed.

II. Matching Network

A given impedance can be matched to 50Ω with two reactive passive components, which are inductors and capacitors. In order to illustrate the effects of these elements on the input impedance, the Smith Chart is used. There are four possible ways of connecting these components to the load which will be matched [1]:

- *a series inductor* moves the impedance along the constant resistance circle clockwise. The inductor value needed to move the reactance on the Smith chart by a factor of X_L is given by

$$L = \frac{X_L}{2\pi f}$$

- *a series capacitor* moves the impedance along the constant resistance circle in a counterclockwise direction. The capacitor value needed to move the reactance on the Smith chart by a factor of X_C is given by

$$C = \frac{-1}{2\pi f X_C}$$

- *a shunt inductor* moves the impedance along the constant conductance circle in an counterclockwise direction. The inductor value needed to move the conductance by Y_L is given by

$$L = \frac{-1}{2\pi f Y_L}$$

- *a shunt capacitor* moves the impedance along the constant conductance circle in a clockwise direction. The capacitor value needed to move the conductance by Y_C is given by

$$C = \frac{Y_C}{2\pi f}$$

The fig. 1 shows above mentioned changes on the Smith Chart.

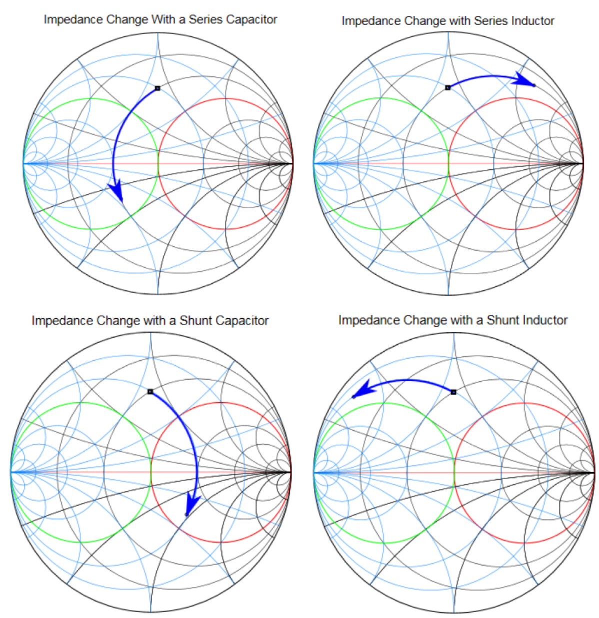


Fig. 1. Smith Charts depicting impedance changes with addition of reactance [1]

The first step of the impedance matching is to bring the impedance to the 50Ω (or $20mS$) circle; then, the next step is to move the impedance to the 50Ω point (the center of the chart).

In the circular loop antenna case, the first step is achieved by connecting a capacitor in parallel and the second step is to connect an inductor in series since the antenna's input impedance is placed to the right bottom of the chart. The steps will be further discussed in the following part.

III. Antenna Design

The antenna is designed with a similar approach in the previous report. The constructed antenna model in HFSS is shown in the Fig. 2.

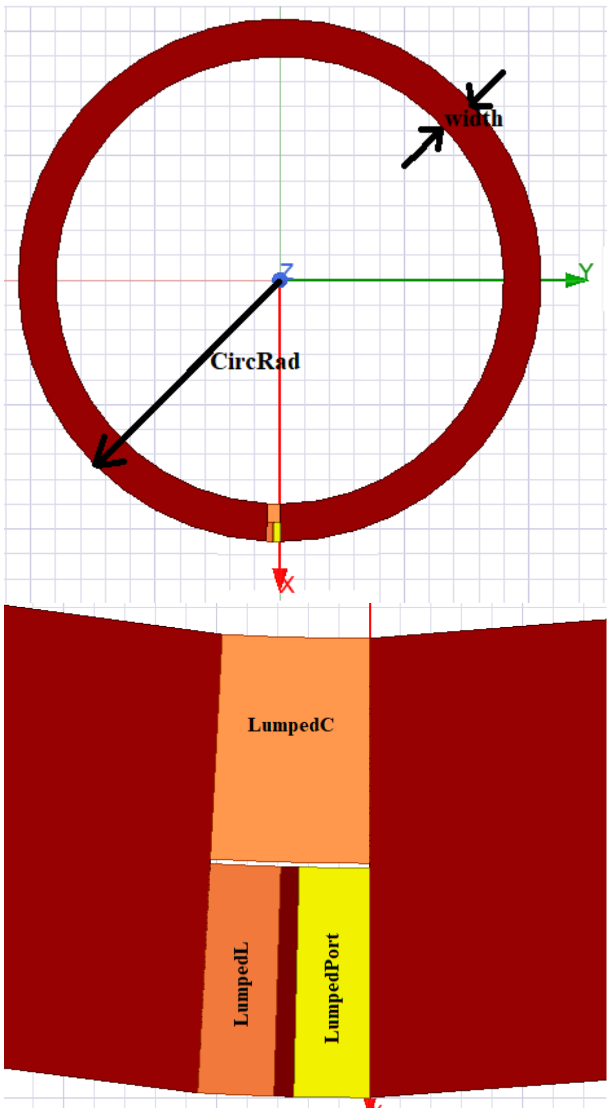


Fig. 2. Antenna model in HFSS

The circumference and the width of the circular loop antenna is adopted from the previous report; so the circular loop radius is $2.1cm$, the loop width is $0.3cm$ and the port width is $0.1cm$.

With the above parameters, the HFSS model (before adding a capacitor and an inductor) is simulated between the frequencies of $2Ghz$ and $5Ghz$; and the obtained input impedance of the antenna is plotted on the Smith Chart which is shown in the Fig. 3.

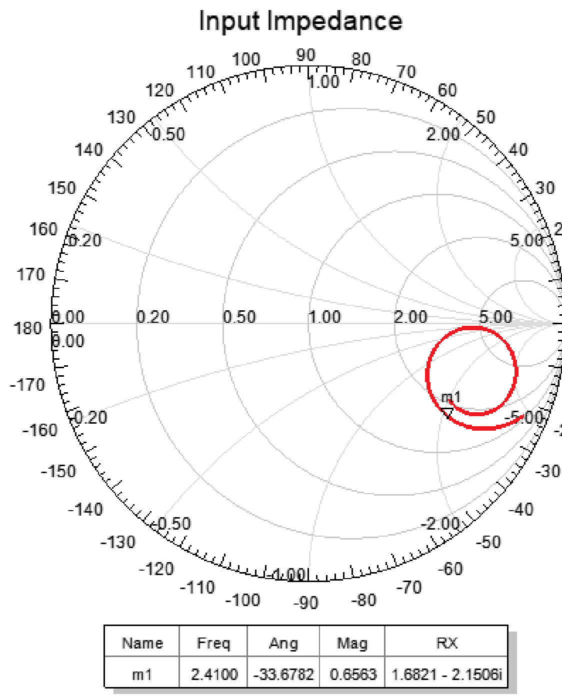


Fig. 3. The input impedance without a matching network

The antenna has an input impedance of $50 * (1.6821 - 2.1506i)\Omega$ at $2.41GHz$. So, in order to move the impedance to the center of the chart (matching to 50Ω), a shunt capacitor and a series inductance are needed.

In order to calculate the values of capacitance and inductance, an online Smith Chart tool [2] is used. The inspected circuit is shown in the Fig. 4.

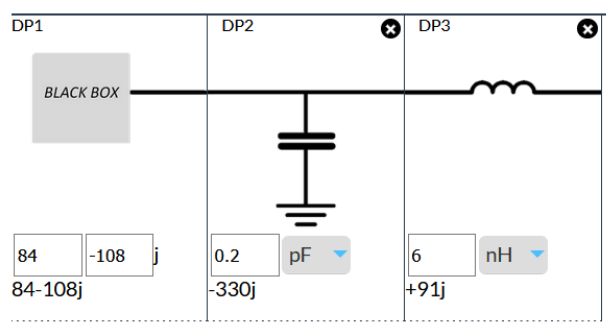


Fig. 4. The circuit of antenna and matching network

The black box has the impedance of the antenna.[1]

[1]Note impedance is looking towards the BLACK BOX.

The effects of adding the specified capacitance and inductance values on the impedance is shown on the Smith Chart in the Fig. 5.

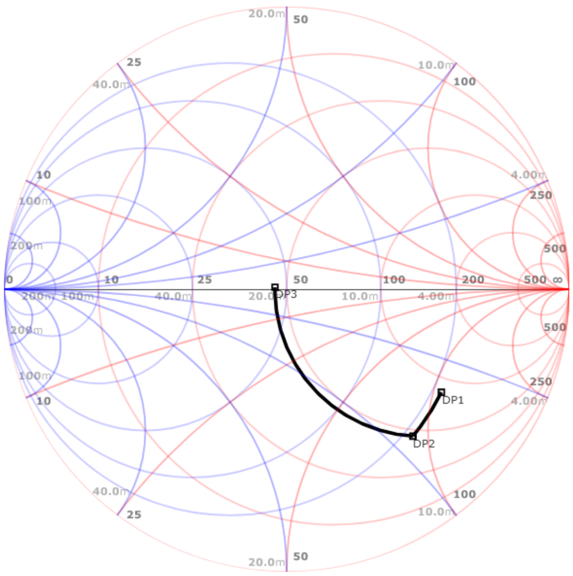
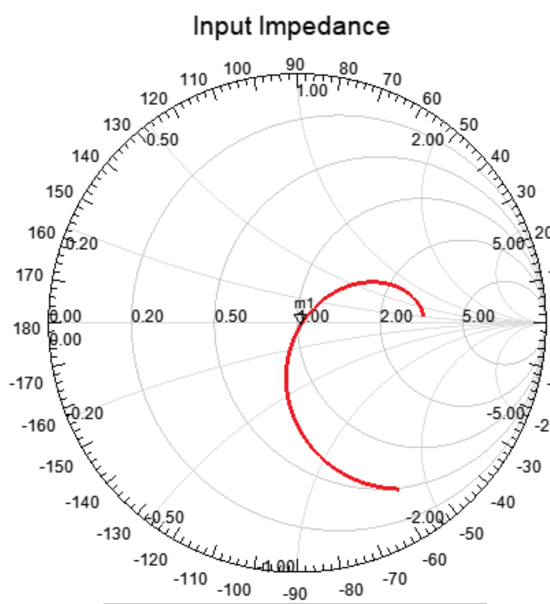


Fig. 5. The effects of adding the capacitor and inductor

The HFSS model with the lumped capacitance of $0.2pF$ in parallel connection and the lumped inductance of $6nH$ in series connection is simulated between the frequencies of $2GHz$ and $3GHz$, and the obtained input impedance of the antenna is plotted on the Smith Chart which is shown in the Fig. 6.



Name	Freq	Ang	Mag	RX
m1	2.4100	-9.5021	0.0179	1.0358 - 0.0061i

Fig. 6. The input impedance with the matching network

The return loss graph of the antenna with the matching network is given in the Fig. 7.

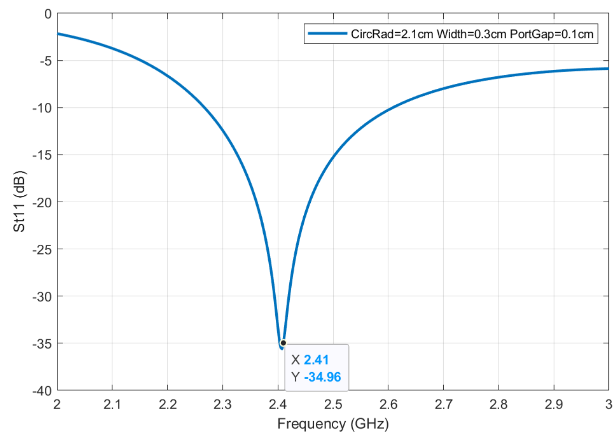


Fig. 7. The return loss of the antenna

The radiation pattern of the antenna with the matching network is given in the Fig. 8.

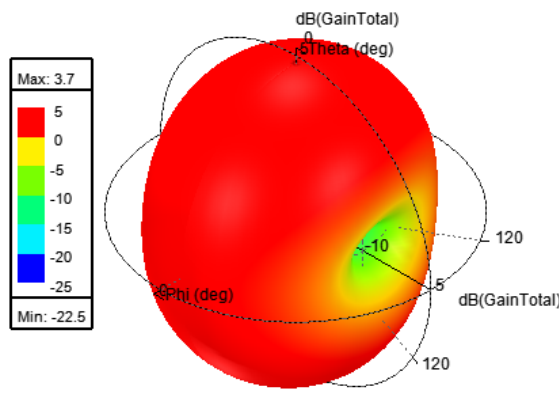


Fig. 8. The radiation pattern of the antenna

IV. Conclusion

The planar circular loop antenna with $2.1cm$ radius, $0.3cm$ width and $0.1cm$ port gap is matched to 50Ω with a matching network of a parallel capacitance of $0.2pF$, and a series inductance of $6nH$. So, with the matching network, the antenna can operate with an approximately 35dB return loss at the specified frequency of $2.4GHz$. However, there exists a drawback of having a matching network, which is whenever the dimensions of the antenna are altered, new values of capacitance and inductance should be calculated and connected.

REFERENCES

[1] Retrieved 14 December 2020, from https://www.cypress.com/file/136236/download

[2] Retrieved 15 December 2020, from https://www.will-kelsey.com/smith_chart/