Circular Loop Antenna Design

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***Abstract*—The design procedure of a circular loop antenna, which works at the resonance frequency of 2.4GHz, is analyzed by the means of the simulation tool of Ansys High Frequency Structure Simulator (HFSS). In fact, the effects of altering the dimensions of the antenna are examined.**

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

I. Introduction

Loop antennas are one of the basic and cheap antenna types, also are not complicated in production and analysis [1]. The loop antennas can be in the shape of rectangle, square, triangle, ellipse, circle and some other configurations. In this implementation, a circular shape is considered and the design procedure and the formulations of the textbook of Antenna Theory Analysis and Design [1] are followed to obtain a circular loop antenna whose resonance frequency is at around 2.4 GHz.

There exists some circular loop antenna implementations such as a printed circular loop antenna with step change in loop width working at the frequency range of 3.5 to 5.1 GHz [2], and a bi-circular loop antenna with plane reflector at 2.45 GHz frequency [3].

II. Antenna Design

The circular loop antenna is designed in HFSS. First, a circle with radius of *wire_rad* is placed at a distance of *torus_rad* from origin. Then, it is swept around the origin by the amount of

$$\frac{2\pi torus\_rad}{2\pi torus\_rad + port\_gap} * 360$$

degree. After obtaining the torus with the given *port_gap*, a line is drawn with length of $2wire\_rad$ across the center of wire. Then it is also swept around the origin by the amount of

$$\frac{port\_gap}{2\pi torus\_rad + port\_gap} * 360$$

degree in order to obtain the excitation port.

The circumference of the circular loop antenna where the self resonance occurs is selected. By referring the input impedance of circular loop antennas, which is shown in the Fig. 1, and choosing $\Omega = 12$, Lommel–Weber function [1], the circumference of the loop is approximately 1.089λ. So, the *torus_rad* can be found at the frequency of $2.4GHz$ as following:

$$r_{torus} = \frac{1}{2\pi}1.089\frac{c}{f} = \frac{1.089}{2\pi}\frac{3*10^8}{2.4*10^9} \approx 2.15cm$$

The radius of the wire is obtained as following expression [1]:

$$\Omega = 12 = 2ln\left(\frac{2\pi r_{torus}}{r_{wire}}\right)$$
$$\rightarrow r_{wire} = 2\pi\frac{2.15cm}{e^6} \approx 0.0335cm$$

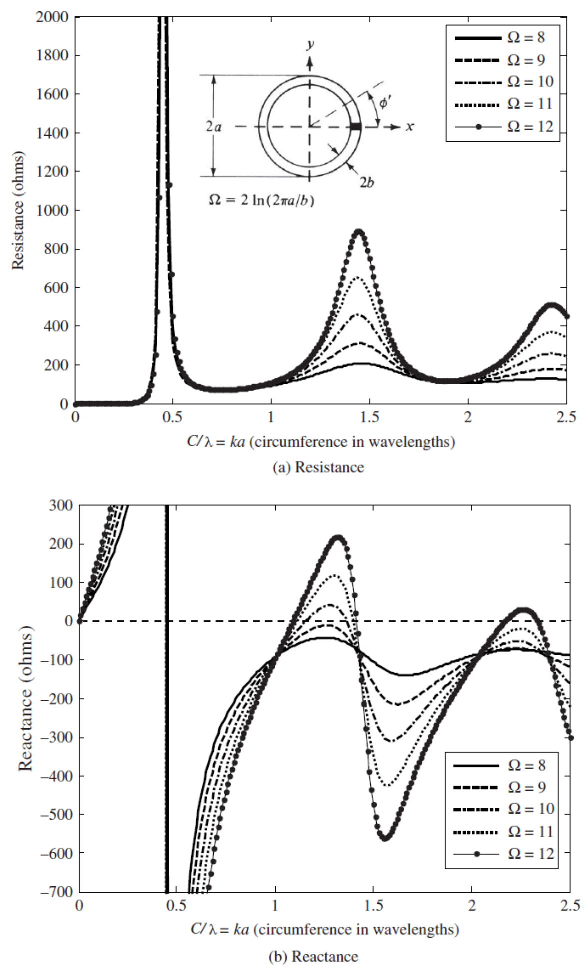

Fig. 1. Input impedance of circular loop antennas[1]

The *port_gap* of the antenna is selected as a value of $0.0335cm$, comparable to the *wire_rad*. The evaluated values of the antenna dimensions are implemented in the HFSS environment.

The Fig. 2 shows the constructed model in HFSS.

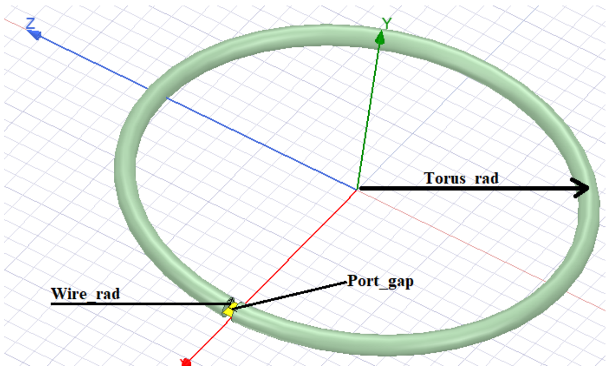

Fig. 2. Model in HFSS

The yellow plane is configured as a lumped port and the material of the solid loop is selected as perfect electric conductor (PEC).

III. Simulation Results

The simulation of the model which is proposed in the previous section with *torus_rad* of $2.15cm$, *wire_rad* of $0.0335cm$ and *port_gap* of $0.0335cm$ is run, and the 3D and 2D radiation pattern of the antenna are given in the Fig. 3.

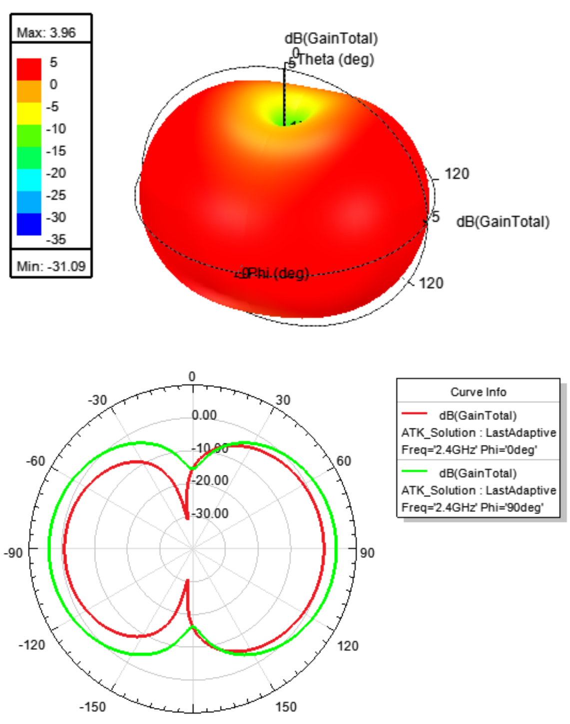

Fig. 3. The gain plots of the antenna

The return loss graph of the simulated antenna is shown in the Fig. 4.

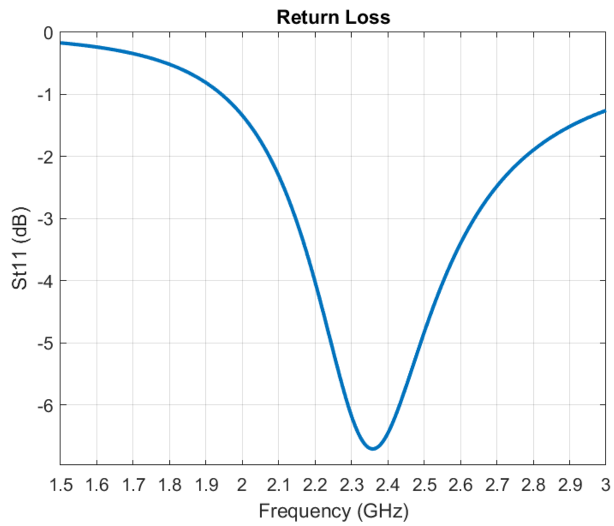

Fig. 4. The return loss graph of the antenna

These values are not as expected to be since the return loss curve should be below at least $-10dB$ at the resonance frequency of $2.4GHz$.

The effects of changing *torus_rad*, *wire_rad*, and *port_gap* are analyzed:

A. Torus Radius:

The torus radius of the antenna is altered from $1.8cm$ to $2.4cm$ by the increments of $0.1cm$ while setting the wire radius and port gap as $0.1cm$, and the Fig. 5 shows the return loss of the selected parameters.

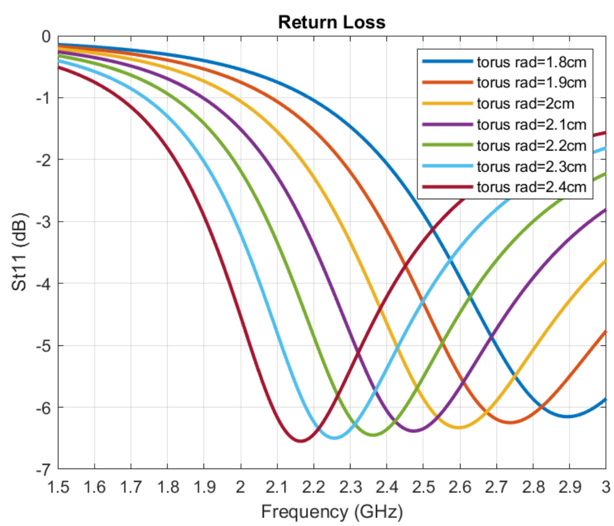

Fig. 5. The effects of changing torus radius on the return loss

So, it can be observed from the above figure that the implemented design behaves like an antenna since as its dimension increases, its resonance frequency becomes lower.

B. Wire Radius:

Two sets of parameters are simulated to observe the effects of varying the wire radius. The first one is to change the wire radius from $0.01cm$ to $0.05cm$ by the increments of $0.01cm$ while setting the torus radius as $2.15cm$ and port gap as $0.03cm$, and the Fig. 6 shows the obtained results.

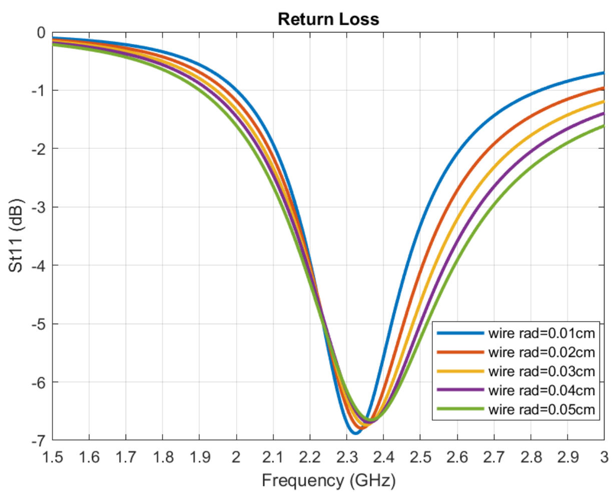

Fig. 6. The effects of smaller increments of the wire radius on the return loss

The second one is to change the wire radius from $0.1cm$ to 0.5 by the increments of $0.1cm$ while setting the torus radius as $2.15cm$ and port gap as $0.1cm$, and the Fig. 7 shows the obtained results.

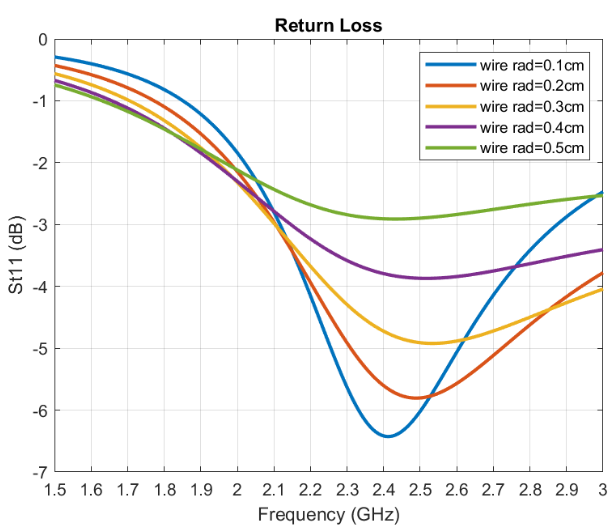

Fig. 7. The effects of larger increments of the wire radius on the return loss

In fact, it is expected that the change in the wire radius will improve the return loss results; however, the estimated impacts of the altering the wire radius does not occur in the above findings.

C. Port Gap:

Similarly, two sets of parameters are simulated to observe the effects of varying the port gap. The first one is to set the port gap $0.03cm$, $0.05cm$, and $0.1cm$ while setting the torus radius as $2.15cm$ and wire radius as $0.03cm$, and the Fig. 8 shows the obtained results.

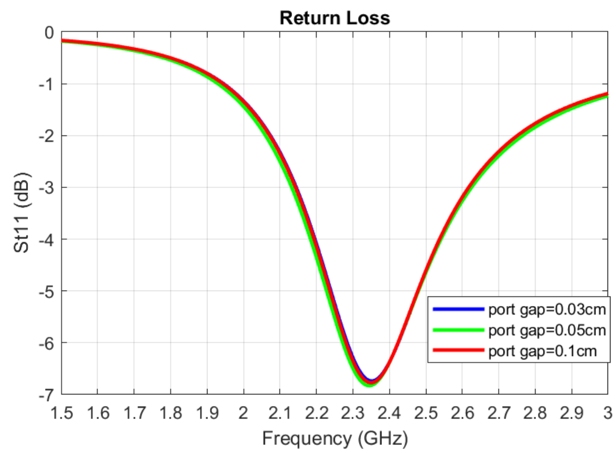

Fig. 8. The effects of smaller increments of the port gap on the return loss

The second one is to change the wire radius from $0.1cm$ to $0.5cm$ by the increments of $0.1cm$ while setting the torus radius as $2.15cm$ and port gap as $0.1cm$, and the Fig. 9 shows the obtained results.

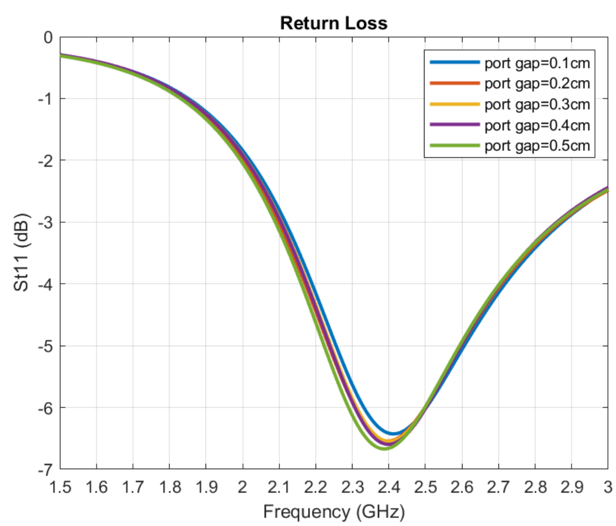

Fig. 9. The effects of larger increments of the port gap on the return loss

IV. Conclusion

An attempt of designing a circular loop antenna which works at the frequency of 2.4Ghz is made; unfortunately, the expected results can not be obtained by altering the wire radius of the antenna. In fact, the change in the torus radius affects the results as expected. In order to match the antenna, a change in its excitation can be made rather than altering its dimensions.

References

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