Homework 2 - Dipole Antenna Design

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***Abstract*—In this report, a wire dipole antenna, which is resonant at 2.4 GHz, is designed. After the design, some optimetrics analysis is done using some dimensions such as dipole length and radius whereas 2D and 3D radiation patterns are demonstrated.**

***Index Terms*—wire dipole antenna, dipole length, dipole radius, radiation pattern, input impedance, bandwith, resonant frequency**

I. Introduction

A dipole antenna, which is also known as dipole aerial or double, is a type of RF (radio frequency) consists of two conductive rods and it has a feed gap in the middle [1]. It is widely used in many areas such as broadcasting, two way radio communcations, and radio reception [2].

Since it is a very fundamentel antenna, it is almost effortless to investigate its properties and the effects of varying its parameters.

II. Wire Dipole Antenna

A. Antenna Design

The wire dipole antenna is modeled using the CAD interface of Ansys High Frequency Structure Simulator. The port is assigned as lumped port. The operating frequency is selected as 2.4 GHz, which is in the ISM band. Considering the operating frequency, dipole length is calculated from the $c = \lambda f$ formula to be 12.49 cm. Since it is half wavelength dipole, its dipole length will be theoretically 6.24 cm. But, in reality we will have a much smaller dipole length. Dipole length, dipole radius, is initialized as 5.62 cm with the help of ACT extensions.

Before the simulation, some solution setup parameters are set. For instance, maximum number of passes, maximum delta s, minimum number of passes, and minimum converged passes are set to 15, 0.01, 2 and 2, respectively. After the simulation is done, maximum magnitude of delta s is reported to be 0.0028, which is below the target 0.01. The antenna dimensions can be seen in Fig. 1.

B. Radiation Pattern and Return Loss

S_{11} plot of the final antenna design is provided in Fig. 2. Its resonant frequency and bandwidth are 2.405 GHz and 0.435 GHz, respectively.

Since the dual of slot antennas are dipole antennas, the radiation patterns of the dipole is omnidirectional, as can be seen in Fig. 3 and Fig. 5.

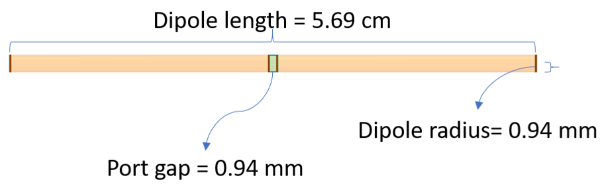

Fig. 1: The antenna dimensions.

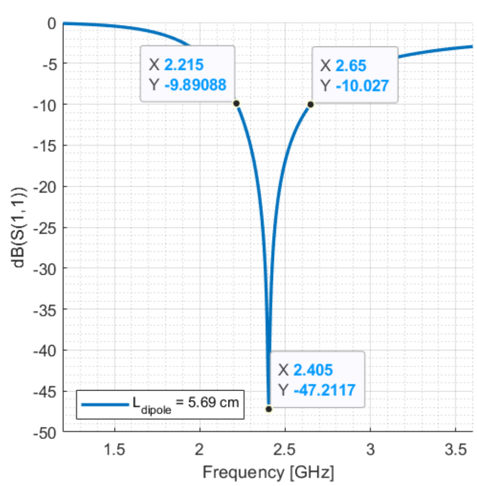

Fig. 2: S_{11} of the dipole antenna.

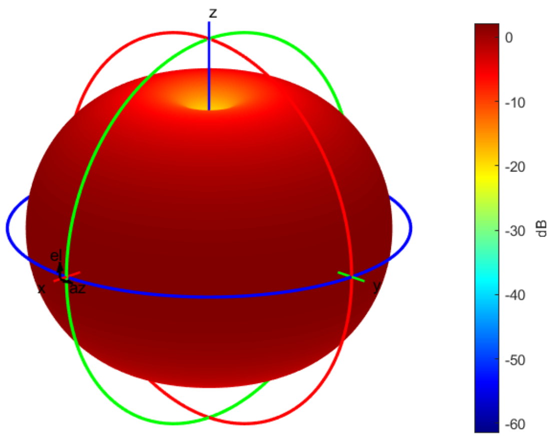

Fig. 3: 3D Directivity Plot

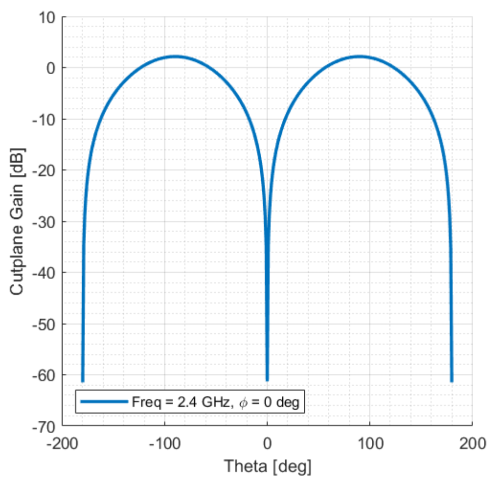

Fig. 4: Cutplane Gain plot of the antenna at 2.4 GHz and ϕ = 0 deg.

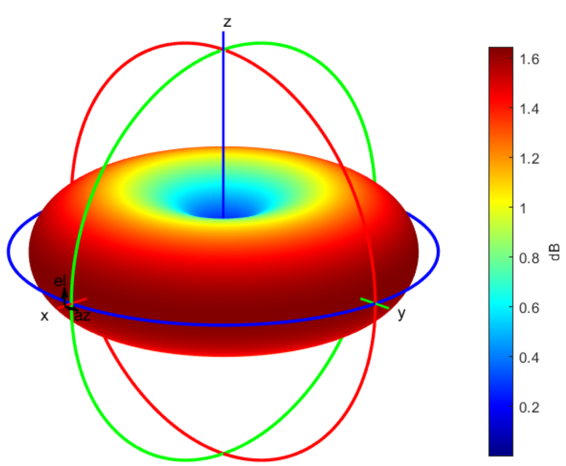

Fig. 5: 3D Gain Plot

TABLE I: Resonant frequency and bandwidth of the antenna for different dipole length values.

L_{dipole} (cm)	Reson. Freq. (GHz)	BW (GHz)
5.52	2.48	0.4521
5.59	2.45	0.4447
5.62	2.43	0.4418
5.67	2.41	0.4357
5.69	2.41	0.4337
5.72	2.39	0.4310

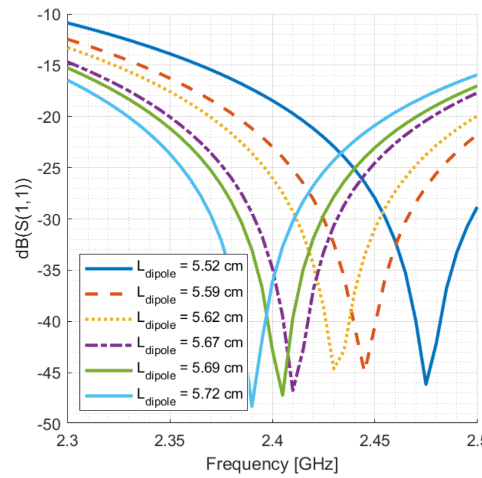

Fig. 6: Return loss of the antenna for different dipole lengths.

III. Parametric Analysis

To understand the antenna properties better, critical dimensions, such as dipole length and radius, are parametrized using optimetrics. While one parameter is swept, the others are kept constant.

A. Dipole Length - Return Loss Relation

The dipole length (L_{dipole}) is set different values in the range of 5.52 cm to 5.72 cm. As can be seen in Table I and Fig. 6, as L_{dipole} increases, both resonant frequency and bandwidth decrease.

B. Dipole Radius

The dipole radius (r_{dipole}) is varied from 0.047 cm to 0.141 cm with a constant step size of 0.0235 cm. As can be seen in Table II and Fig. 7. As r_{dipole} decreases, the resonant frequency also decreases but the bandwidth increases.

C. Dipole Radius Input Impedance Relation

In [3], it is stated that the real part of the input impedance of the dipole antenna is 73. As can be seen in Fig. 8, curves are located approximately crosses the horizontal line on 1.0, which corresponds to this real value. As the dipole radius increases, the input impedance also slightly increases.

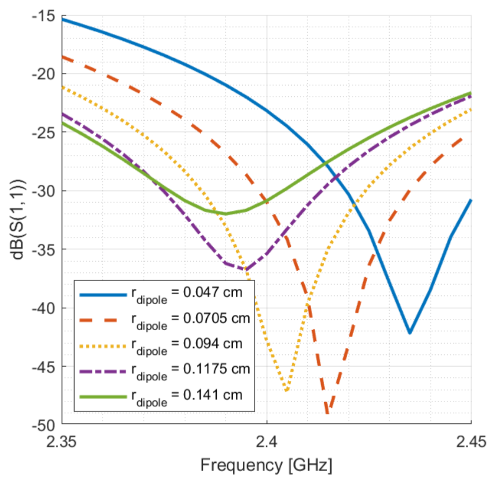

Fig. 7: Return loss of the antenna for different dipole radii.

TABLE II: Resonant frequency and bandwidth of the antenna for different values of dipole radius.

r_{dipole} (cm)	Reson. Freq. (GHz)	BW (GHz)
0.047	2.44	0.353
0.0705	2.42	0.396
0.094	2.41	0.434
0.1175	2.40	0.468
0.141	2.39	0.499

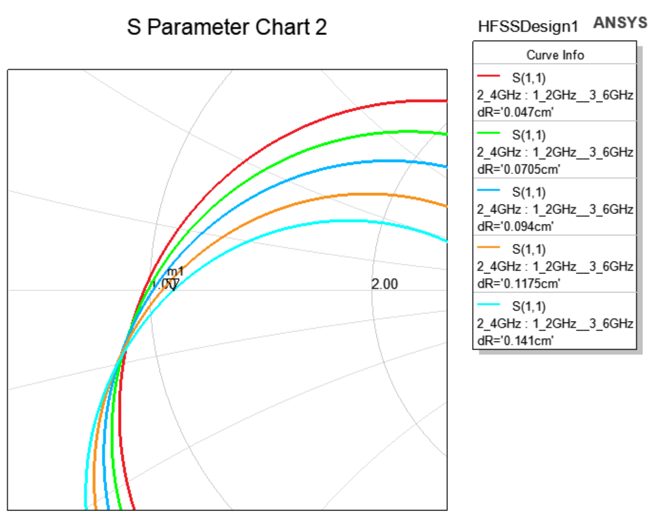

Fig. 8: The input impedance - dipole radius relation on a Smith chart.

IV. Conclusion

In this paper, the effects of varying the dipole length and radius is discussed. It is found out that as both the dipole length and radius increase, the resonant frequency decreases. Also, an increase in dipole length results in a decrease in the resonant frequency while the dipole radius has the opposite effect.

References

[1] https://www.electrical4u.com/dipole-antenna/
[2] https://www.electronics-notes.com/articles/antennas-propagation/dipole-antenna/dipole-antenna-aerial.php
[3] Balanis, Constantine A. Antenna Theory: Analysis and Design. New York: Harper Row, 1982. Print.