EEC133 Lab 2: Loop Antennas

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Contents

Pre-Lab

Part 1: Loop Antenna Design

Questions:

1. $r = 0.0064$m. $\lambda = \frac{c}{f} = 0.12$m. $r \leq \frac{\lambda}{6\pi} \approx 0.00637$m.

2.

$$\text{Radiation Resistance: } 320\pi^6 \left(\frac{0.00637}{0.12}\right)^4 = 2.44\Omega$$

$$\text{Directivity: } 1.5$$

$$\text{Half-power beamwidth: } \frac{\pi}{2}$$

$$\text{Far Field Requirement: } r >> \frac{0.12}{2\pi} = 0.019\text{m}$$

3. $C = 90$ fF. Since $R_A = 18.32\Omega$, $X_A = 705.38\Omega$, and $\omega = 2\pi \times 2.5 \times 10^9$, $C = \frac{X_A}{\omega(R_A^2 + X_A^2)} = 2.34$ fF

4. (a) Screenshot of HFSS Model

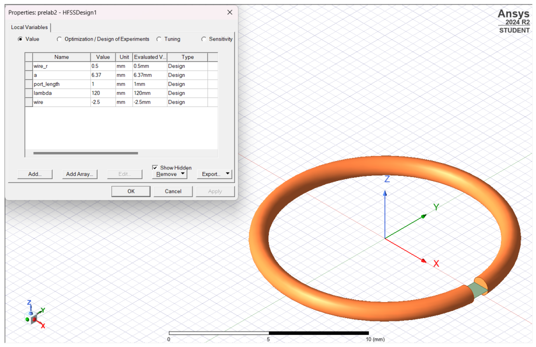

Figure 1: HFSS Loop Antenna Model

(b) The return loss plot shows the $20 \log |\Gamma|$, the reflection coefficient of the antenna, across different frequencies.

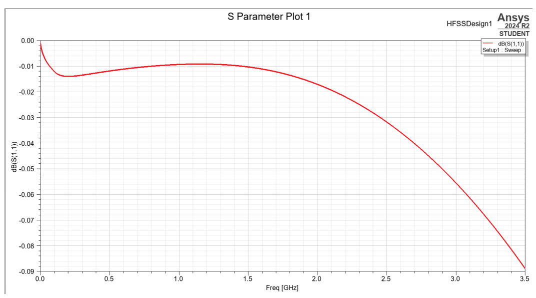

Figure 2: $S_{1,1}$ Parameter

(c) Plot the 3D directivity pattern at 2.5 GHz.

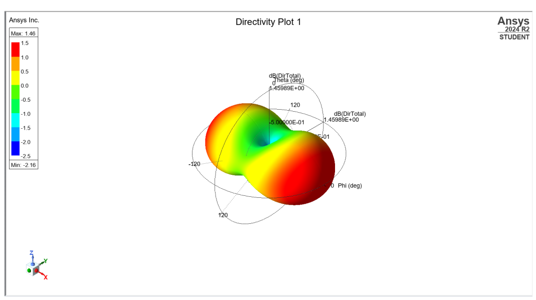

Figure 3: 3D Directivity Pattern at 2.5 GHz

(d) Plot the directivity pattern with $\phi = 90°$ and $0° \geq \theta \leq 180°$.

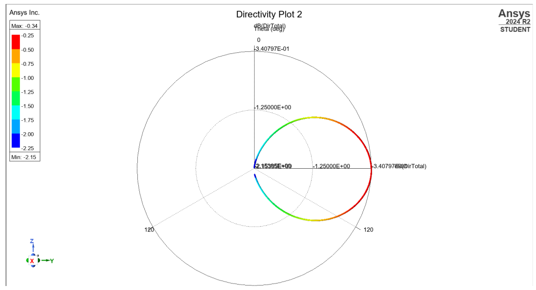

Figure 4: Directivity Pattern at $\phi = 90°$

(e) The expected input resistance is 2.44Ω, but the simulated resistance is 18.32Ω, so the results are very different. However, the simulated reactance makes sense because it's very large compared to the resistance. Therefore, the reflection coefficient is about -1, which matches the $S_{1,1}$ plot at 2.5 GHz.

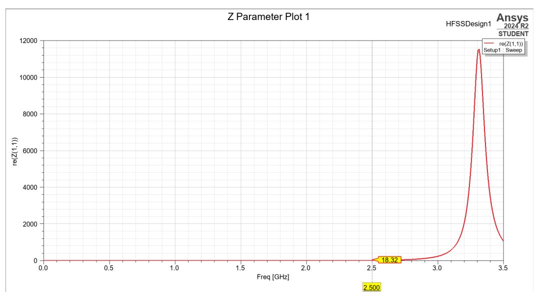

Figure 5: $\mathrm{Re}(Z_{1,1})$ at 2.5 GHz

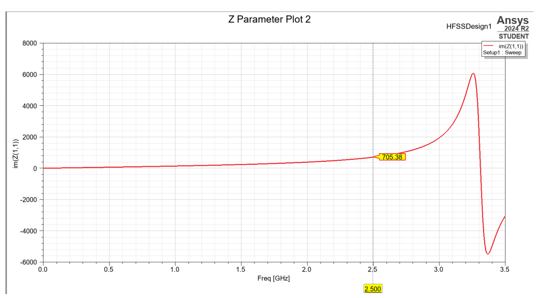

Figure 6: $\mathrm{Im}(Z_{1,1})$ at 2.5 GHz

(f) To find the radiation efficiency, we'll plot the gain at 2.5 GHz and use $e = \frac{G_0}{D_0}$ Since $G_0 = 1.35$ dB and $D_0 = 1.46$ dB, the efficiency is 92.5%.

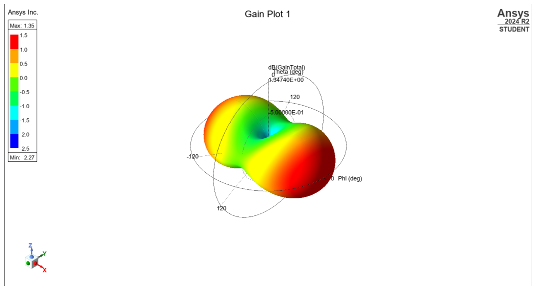

Figure 7: Antenna Gain at 2.5 GHz

(g) The electric field at $z = 10$ mm plane.

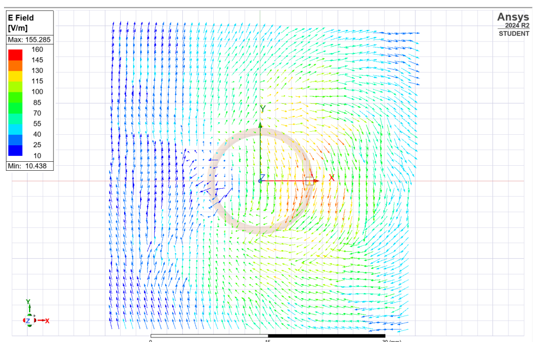

Figure 8: Electric Field

(h) The magnetic field at $z = 10$ mm plane.

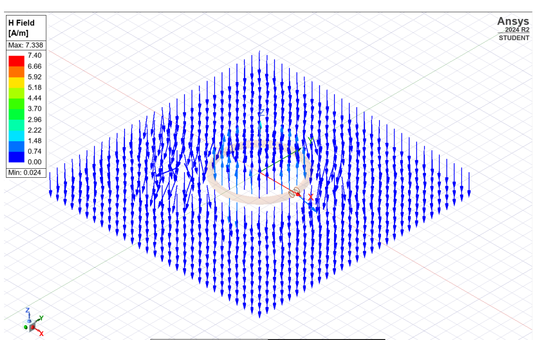

Figure 9: Magnetic Field

(i) The plots make sense because the magnetic field looks like the dipole field.

(j) No. The antenna's input resistance is too small, making the 50Ω transmission line hard to match its impedance.

Part 2: More Noise Calculations

Questions:

1. R_{in} and R_{out} are typically 50Ω to avoid wave reflection in R_{in} by matching the characteristics impedance in the input and output transmission line. R_{out}

2. Noise =
$$9.1 \times 10^{-10} \frac{V}{\sqrt{Hz}}$$
This unit means that the noise voltage is $9.1 * 10^{-10}$ volts per unit of the frequency bandwidth.

3. $R_{in} = 0.489\Omega$, so $\tau = 0.019$. The small transmission coefficient implies that very little power will be transmitted to the amplifier, so the signal amplification will be poor.

Post-Lab

Questions:

1. Total length = 0.3 m. The original length is accurate enough as lab 1 measurements showed.

2. Resonant frequency at 1.06 GHz. The loop is 0.94 fraction of wavelengths. The result shows that reflection from the antenna is minimized at 1.06 GHz.

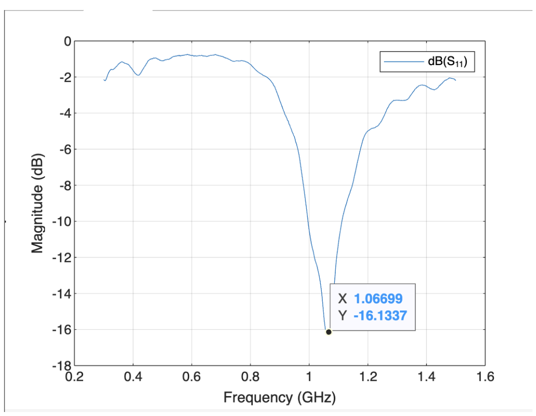

Figure 10: $S_{1,1}$ at 90°

3. The input impedance makes sense because the real and imaginary parts has similar shape to that of the simulated results. However, the scale of the impedance is much smaller than those of the simulation.

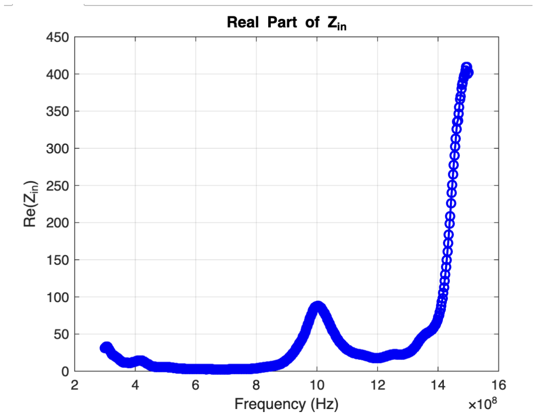

Figure 11: Real Part of Input Impedance

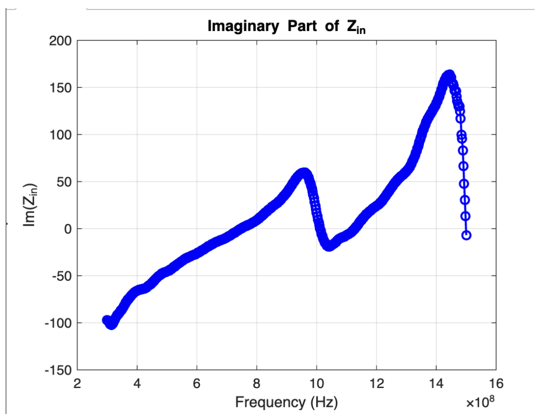

Figure 12: Imaginary Part of Input Impedance

4. The radiation pattern roughly corresponds to a $\sin^2(\theta)$ function, which matches the calculations from the lecture.

Angle (degrees)	S_{21} **(dB)**
0	-47.5568
10	-43.7025
20	-43.4709
30	-37.9321
40	-38.1531
50	-37.0680
60	-35.2296
70	-35.4238
80	-34.4441
90	-35.7184
100	-36.4169
110	-38.5529
120	-39.9543
130	-42.2198
140	-45.5597
150	-47.8392
160	-51.1367
170	-49.8512
180	-44.6069

Table 1: S_{21} when Dipole Antenna Faces Different Angle

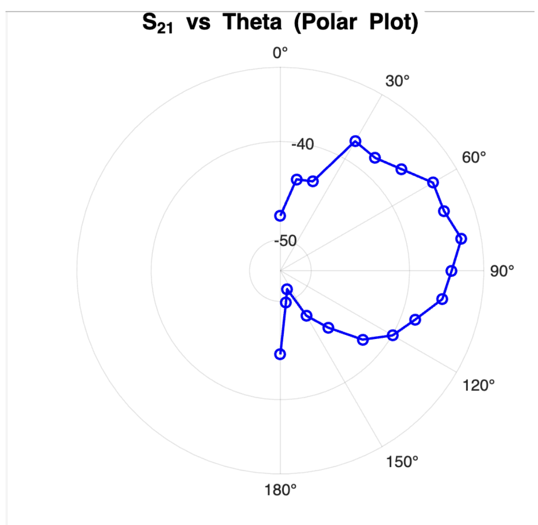

Figure 13: Polar Plot of S21

5. The $S_{2,1}$ measured at step 4 is -33 dB. Before turning the antenna, we measured that $S_{2,1} = -44.6$ dB. The transmission coefficient increases after we turned the antenna, likely because the field's polarization of the transmitter antenna better matches that of the receiver antenna.