EEC133 Pre-Lab 1: Dipole Antennas and Noise

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Contents

Part 1: Dipole Antenna Design

- **Operating frequency:** 1.5 GHz
- **Length:** short dipole ($l \leq \frac{\lambda}{10}$)
- **Wire radius:** 0.5mm
- **Input impedance:** no requirement

Questions:

1. $l = 20$ mm

   We can find the wavelength λ by $\lambda = \frac{c}{f} = \frac{3\times10^8\,\mathrm{m\,s^{-1}}}{1.5\times10^9\,\mathrm{Hz}} = 0.2\,\mathrm{m}$.

   The length of the dipole antenna is $l \leq \frac{\lambda}{10} = 20\,\mathrm{mm}$.

   Since the radiated power depends quadratically on l, the maximum l gives the maximum radiated power.

2.
$$R_{rad} = 20\pi^2\left(\frac{l}{\lambda}\right)^2 = (20\pi^2)\left(\frac{0.02}{0.2}\right)^2 = 1.97\,\Omega$$
$$D_0 = 1.5$$
$$F(\theta,\phi) = \sin^2(\theta)$$
$$\text{HPBW} = \theta_2 - \theta_1 = 0.785 - (-0.785) = 1.57$$
$$\text{Far Field Requirement}: kr >> 1 \implies r >> \frac{\lambda}{2\pi} = 0.03\,\mathrm{m}$$

3. The normalized radiation intensity is radiation intensity of all direction normalized by the maximum radiation intensity.

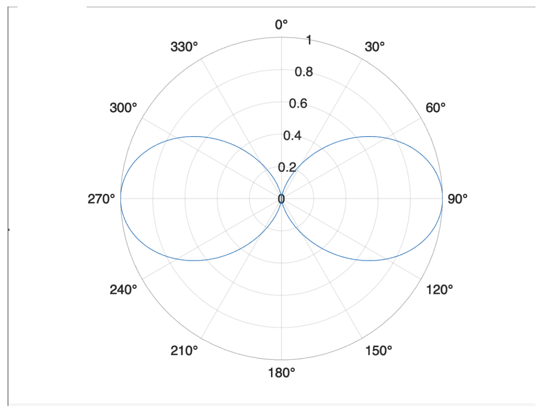

Figure 1: Normalized Radiation Intensity of the Dipole Antenna

4. HFSS Simulation

   (a) Dipole Antenna Model

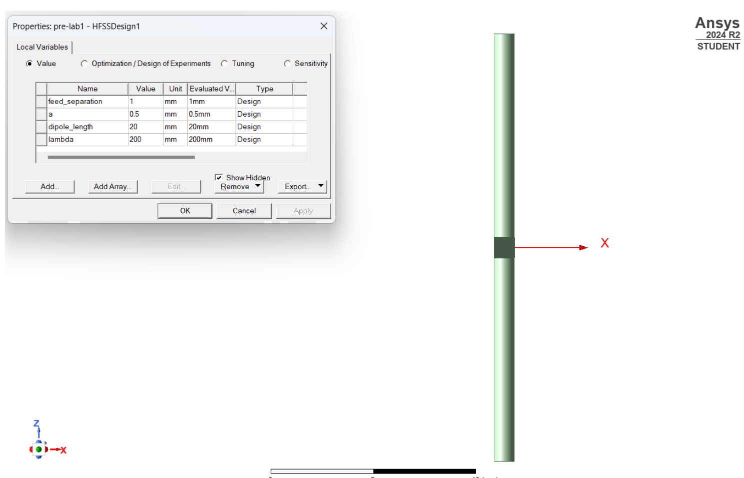

Figure 2: Dipole Antenna Model

   (b) S-Parameter The S-Parameter frequency sweep plot shows that as the frequency increases, less of the input wave is reflected back.

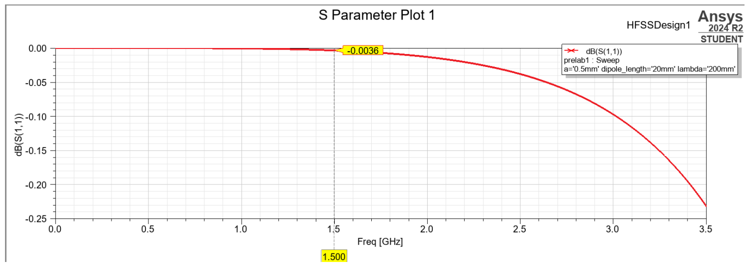

Figure 3: S-Parameter Frequency Sweep

(c) 3D Directivity Pattern

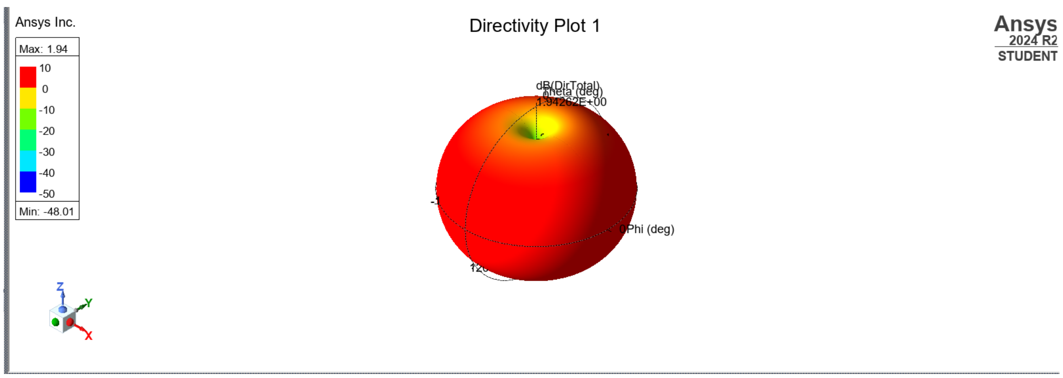

Figure 4: 3D Directivity Pattern

(d) Input impedance

$$Z_{in} = 1.81 - j658.82$$

The real part of the z parameter is less than the radiation resistance calculated in (2). The reactance make sense because the dipole antenna is geometrically similar to a capacitor. As a result, it has high reactance at low frequency, and low reactance at high frequency.

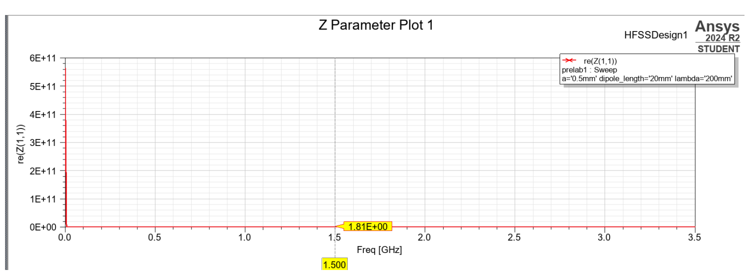

Figure 5: $re(Z(1,1))$

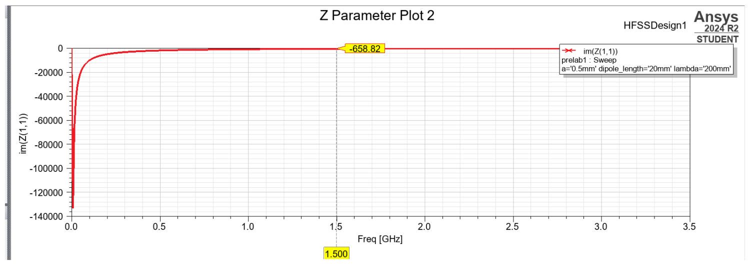

Figure 6: $im(Z(1,1))$

(e) The Electric Field

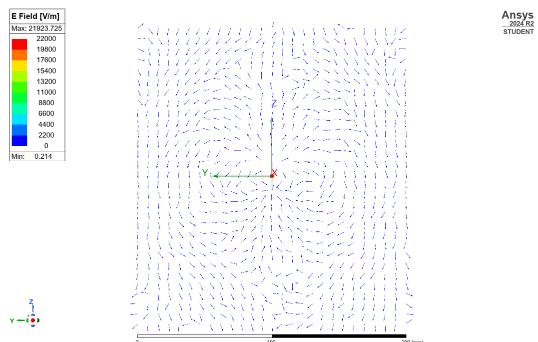

Figure 7: $\vec{E}$ Field

(f) The Magnetic Field

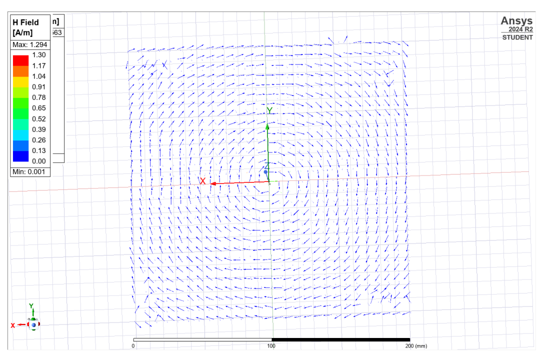

Figure 8: $\vec{H}$ Field

(g) The antenna is not a good transmitter because R_{rad} is small, so it's hard to match its impedance and reduce reflected power. Moreover, most of the power sent to the antenna will get reflected because of the large S-parameter.

Part 2: Basic Noise Calculations

1. Approximate Noise Level = $-102\,\mathrm{dBm}$

2. $$P_n = \left(1.38 \times 10^{-23}\,\frac{\mathrm{J}}{\mathrm{K}}\right)(298.15\mathrm{K})(1 \times 10^{6}\mathrm{Hz}) = 4.1 \times 10^{-15}\mathrm{W}$$
$$\text{Expected Noise Level} = 10\log\left(\frac{P_{in}}{10^{-3}}\right) = -113.9\ \mathrm{dBm}$$

3. $$P = (1\ \mathrm{mW})\left(10^{\frac{-102\mathrm{dBm}}{10\mathrm{dBm}}}\right) = 6.3 \times 10^{-14}\mathrm{W}$$

4. In both cases, spikes could be observed in the 2.4 - 2.4 GHz range. However, the spikes are bigger when the antenna is attached. These spikes are from the bluetooth signals.

5. Yes, the electric field from the bluetooth wave induces current oscillations in the transmission line. The time-varying current carries AC power, which is plotted on the network analyzer. When the transmission line is opened at the end, the impedance is purely reactive, thus no power is dissipated. Therefore, no power is detected in the analyzer except those from the resistor's thermal noise. As a result, we only see a weak signal because it's only caused by the thermal noise.