λ_0 = 0.3m

1. PEC Antenna
    a. $0.1\lambda_0$

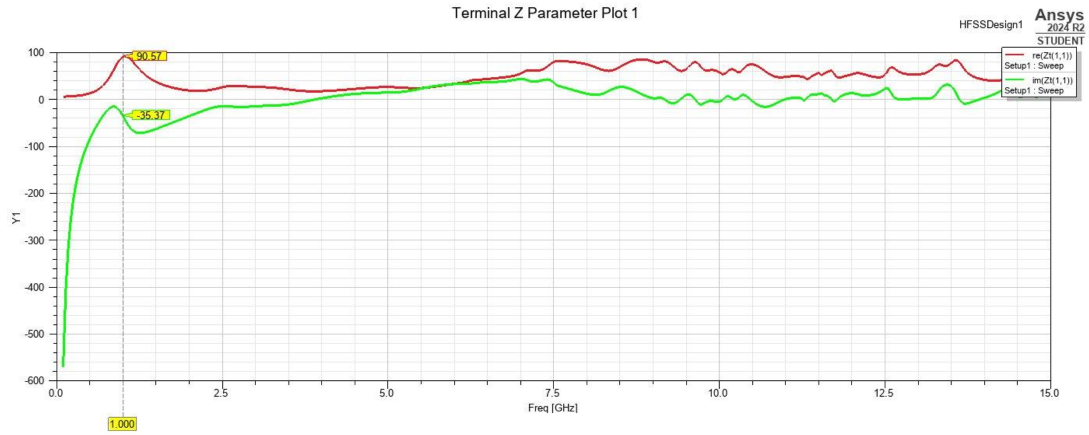

Figure 1: Z Parameter for d =0.1λ_0

    b. $0.01\lambda_0$

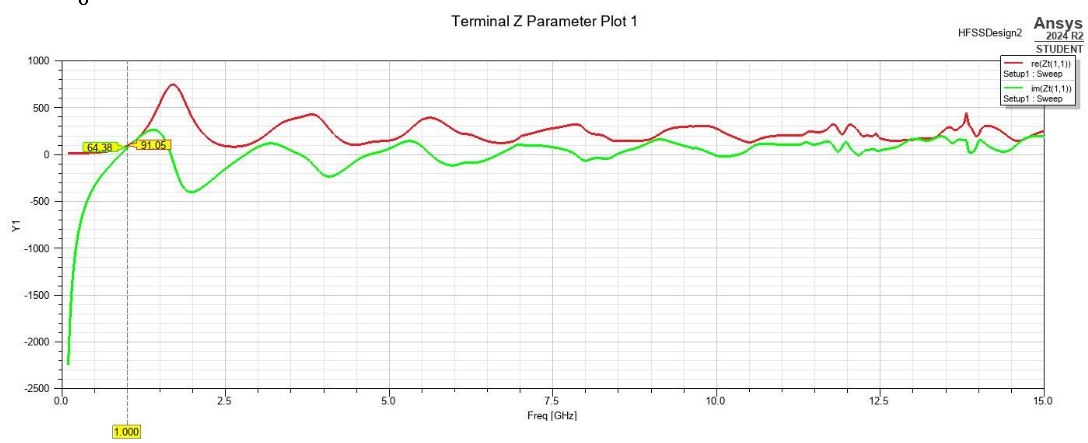

Figure 2: Z Parameter for d =0.01λ_0

    c. $0.001\lambda_0$

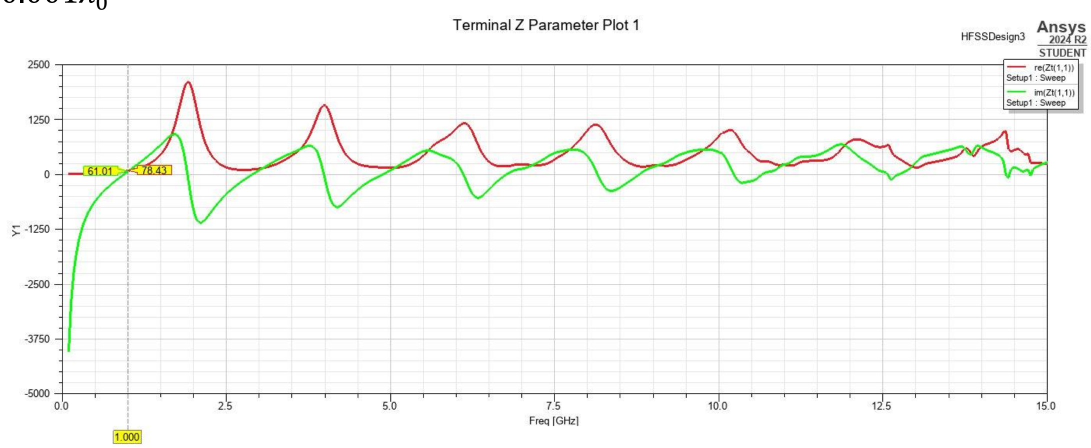

Figure 3: Z Parameter for d =0.001λ_0

    d. $0.0001\lambda_0$: Simulation refused to run, throwing the following error:

2. Gain (maximum gain) for each of the PEC antenna
    a. $0.1\lambda_0$

Figure 4: Maximum gain for d =0.1λ_0 at 90°

b. $0.01\lambda_0$

Figure 5: Maximum gain for d =0.01λ_0 at 90°

c. $0.001\lambda_0$

Figure 6: Maximum gain for d =0.001λ_0 at 90°

3. Copper Antenna
   a. $0.1\lambda_0$

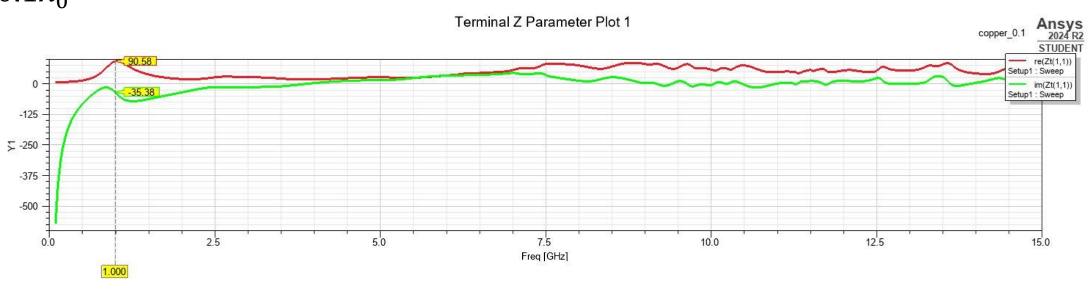

Figure 7: Z Parameter for d =0.1λ_0

b. $0.01\lambda_0$

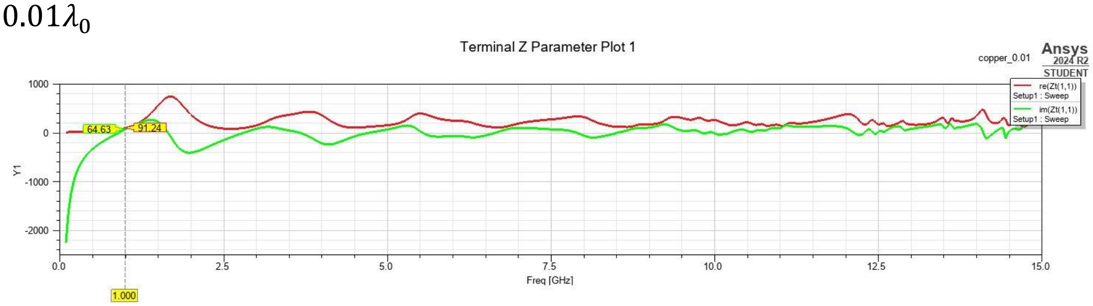

Figure 8: Z Parameter for d =0.01λ_0

c. $0.001\lambda_0$

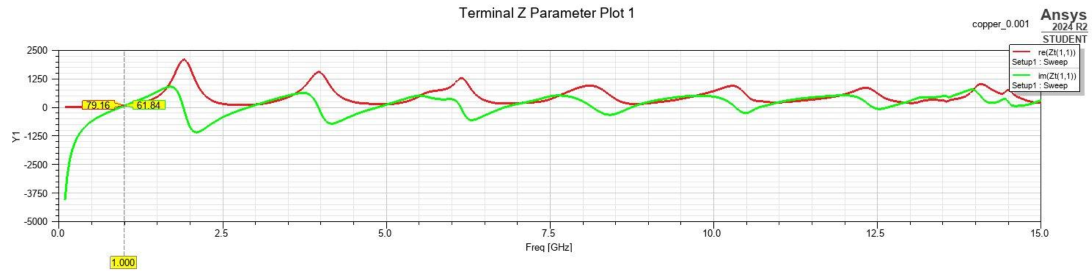

Figure 9: Z Parameter for d =0.001λ_0

d. $0.0001\lambda_0$: Simulation again, refused to run, throwing the following error:

4. Gain (maximum gain) for each of the copper antenna
   a. $0.1\lambda_0$

Figure 10: Maximum gain for d =0.1λ_0 at 90°

   b. $0.01\lambda_0$

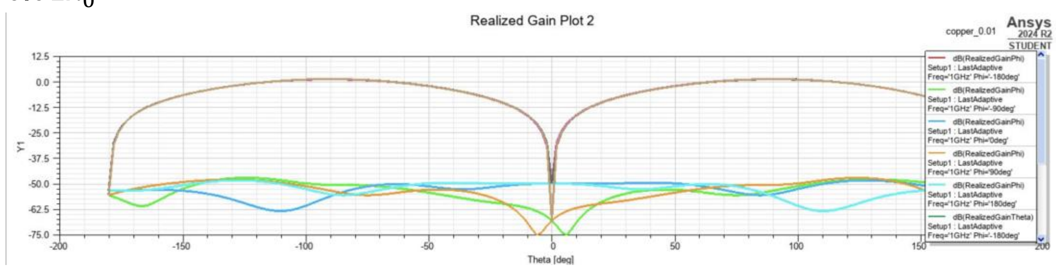

Figure 11: Maximum gain for d =0.001λ_0 at 90°

   c. $0.001\lambda_0$

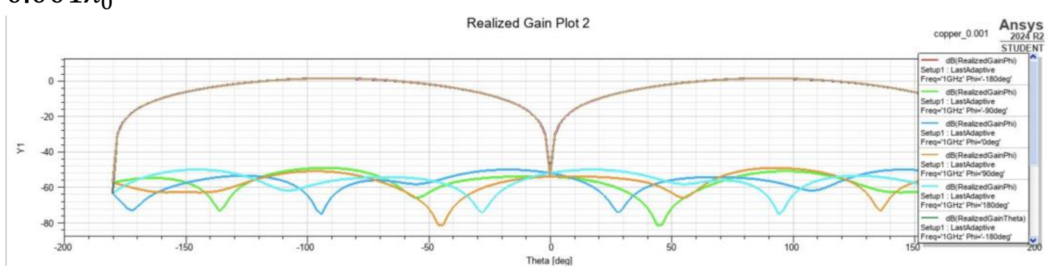

Figure 12: Maximum gain for d =0.0001λ_0 at 90°

5. Observations
   a. We found it interesting that at a diameter of $0.1\lambda_0$, the PEC and copper antenna have basically identical realized gain plots. However, at smaller diameters ($0.01\lambda_0$, $0.001\lambda_0$), the antennas behave slightly differently. This may just be due quantization errors or numerical instabilities. < Not sure if this is correct
   b. In both the PEC and copper antennas, the d=$0.1\lambda_0$ antenna's reactance is capacitive at 1GHz. However, the reactances of the d=$0.01\lambda_0$ and d=$0.001\lambda_0$ antennas were inductive. This might be due to the larger surface area of the feed gap in the d=$0.1\lambda_0$ antenna, creating a higher parasitic capacitance.

c. We also found it interesting how the s-parameters varied with the antenna diameter. At d=$0.1\lambda_0$, there's a defined dip in S(1,1) around 1GHz, but we only see distinct dips in S(1,1) at odd multiples of 1GHz (3GHz, 5GHz, 7GHz, etc.) in the smaller diameter antennas (PEC or copper).

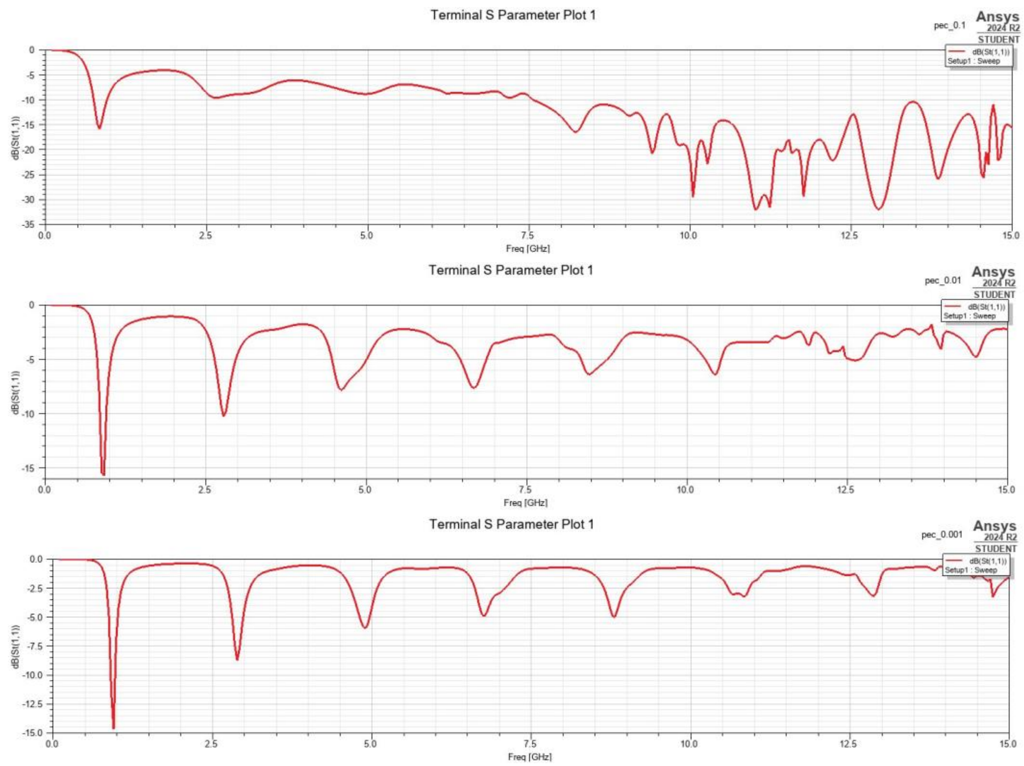

Figure 13: PEC Antenna S(1,1) Plots for d = $0.1\lambda_0$, $0.01\lambda_0$, and $0.001\lambda_0$

We assume this is because the large diameter antenna has higher-order modes which are at lower frequencies, and therefore more excitable. The smaller diameter antenna pushes these high-order modes to higher frequencies, so the length-mode resonances are more distinct.

We are curious to how this effect would affect the performance at higher operating frequencies (especially ones which aren't odd-multiples of 1GHz). The thicker antenna seems to have a lower average reflection coefficient above 1GHz, so it should be more efficient as a wideband antenna.

Below are Electric Field Simulations:

We notice in the radiation pattern that the lobes are extending broadside (perpendicular to the dipole) along the X-Y plane are expected. Additionally, half-wave dipole has its maximum radiation in the plane orthogonal to the antenna axis (which is Z-axis in your setup). That's why the main lobes extend sideways from the dipole. Another radiation pattern we can mention is the nulls along the Z-axis (the axis of the dipole). This is also expected as it is the direction where minimal radiation is present.

As we analyze the far field view, we notice the "peanut" like pattern analogous to the classic donut shaped far-field pattern from a dipole antenna sliced vertically.

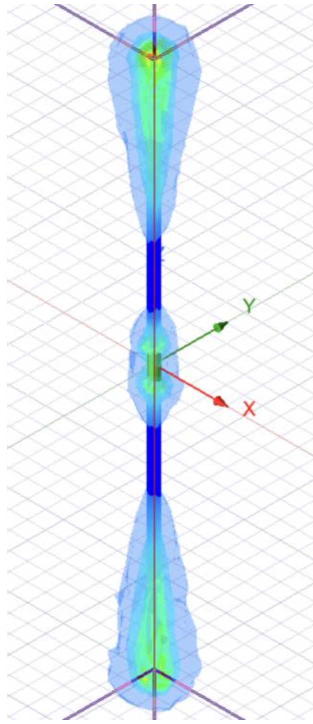

Figure 14: E-field seen from “Fit All” view

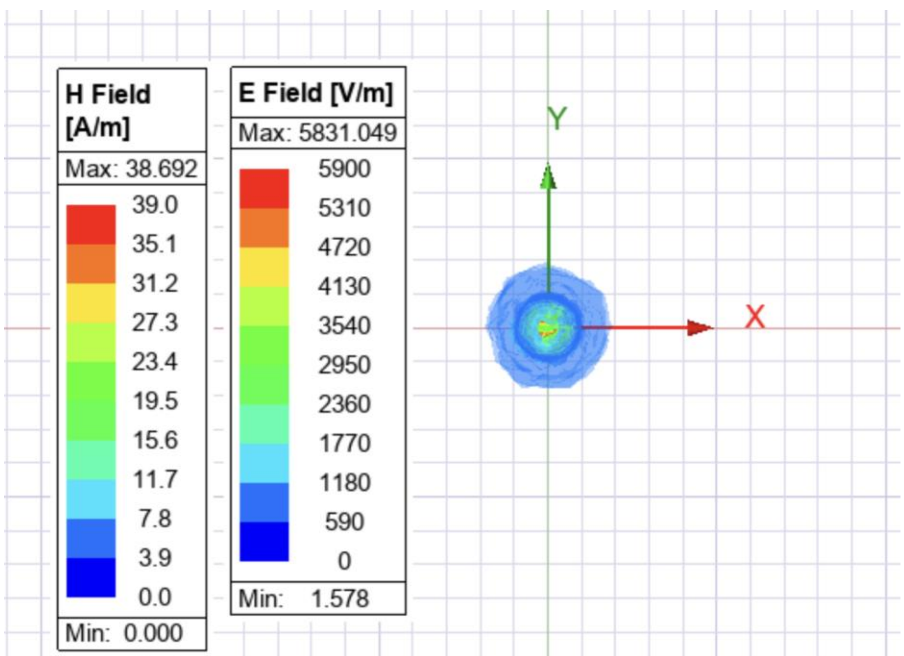

Figure 15: E-field seen from top

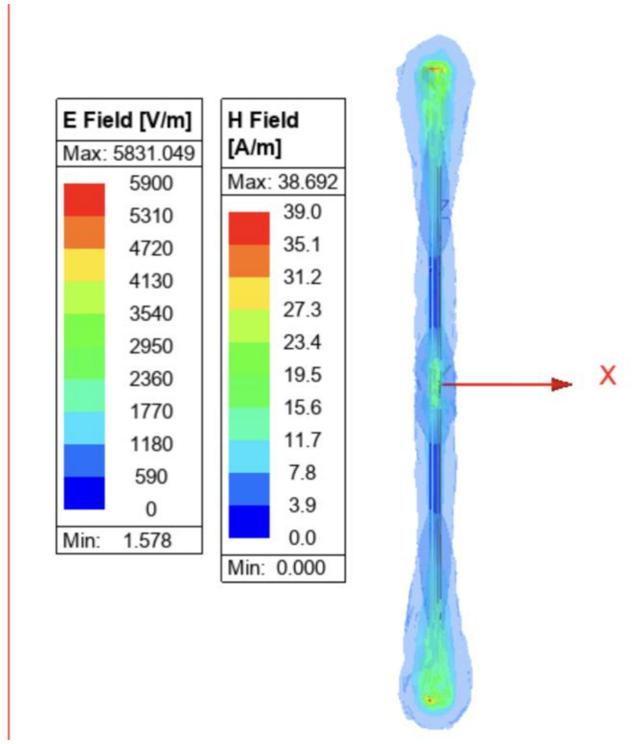

Figure 16: E-field seen from Y axis

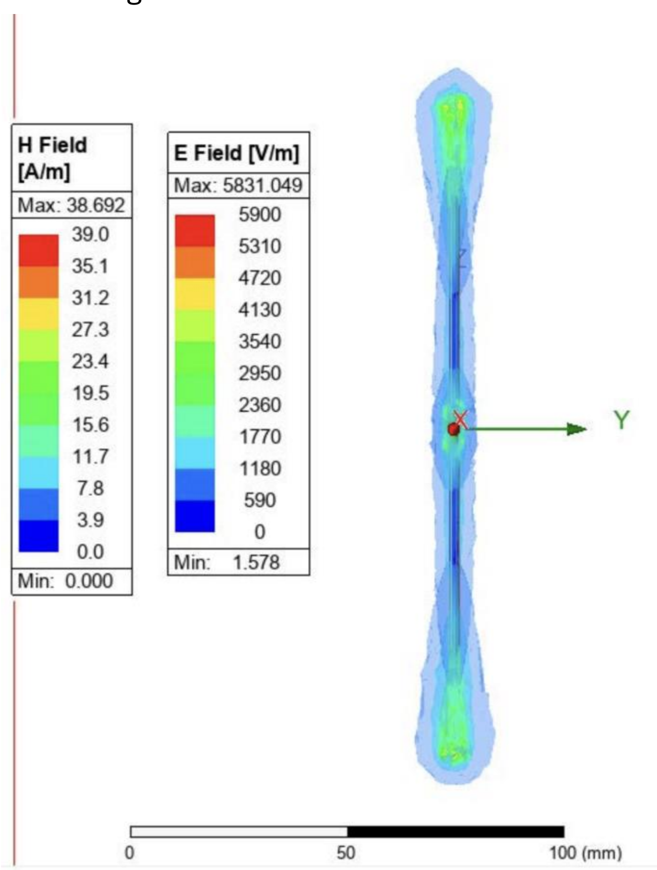

Figure 17: E-field seen from Y axis