ECEN5134 Homework 10

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1 Problem 1

1.1 (a)

As the first part of the problem, the helical antenna is placed on an infinite PEC ground. The number of turns ($turns$) of the antenna is varied using the parametric sweep from $turns = 3$ to $turns = 8$. Simulations are carried out with frequency sweeps from 1GHz to 2GHz, and this range also consists of the GPS L1 band, which is 1.575GHz. To design the axial mode helical antenna, the specifications from slide 21 are selected. The pitch angle α is selected to be 13° since it is chosen from the range $12^{\circ} < \alpha < 14^{\circ}$. As for the circumference (C) of the turns, we choose from range $\frac{3}{4}\lambda_0 < C < \frac{4}{3}\lambda_0$. Since $f_0 = 1.575\text{GHz}$, $\lambda_0 = 0.19\text{m}$. For simplicity, we choose $C = \lambda_0$. The wire thickness is selected to be 1mm. Based on these specifications, the helical antenna in 1 is made.

The plots below illustrated the impact as the number of turns is increased. It should be noted that the polar plots are made at the GPS L1 band frequency.

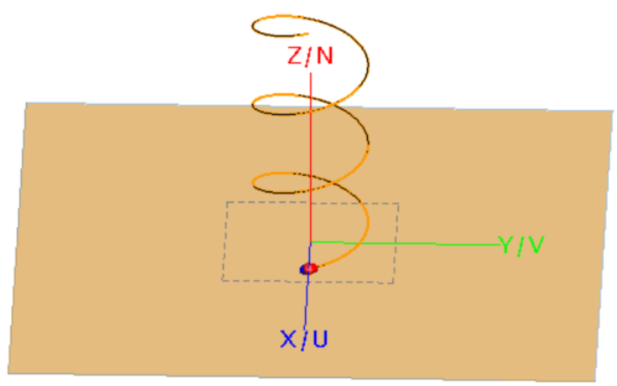


Figure 1: Helical antenna on infinite PEC ground.

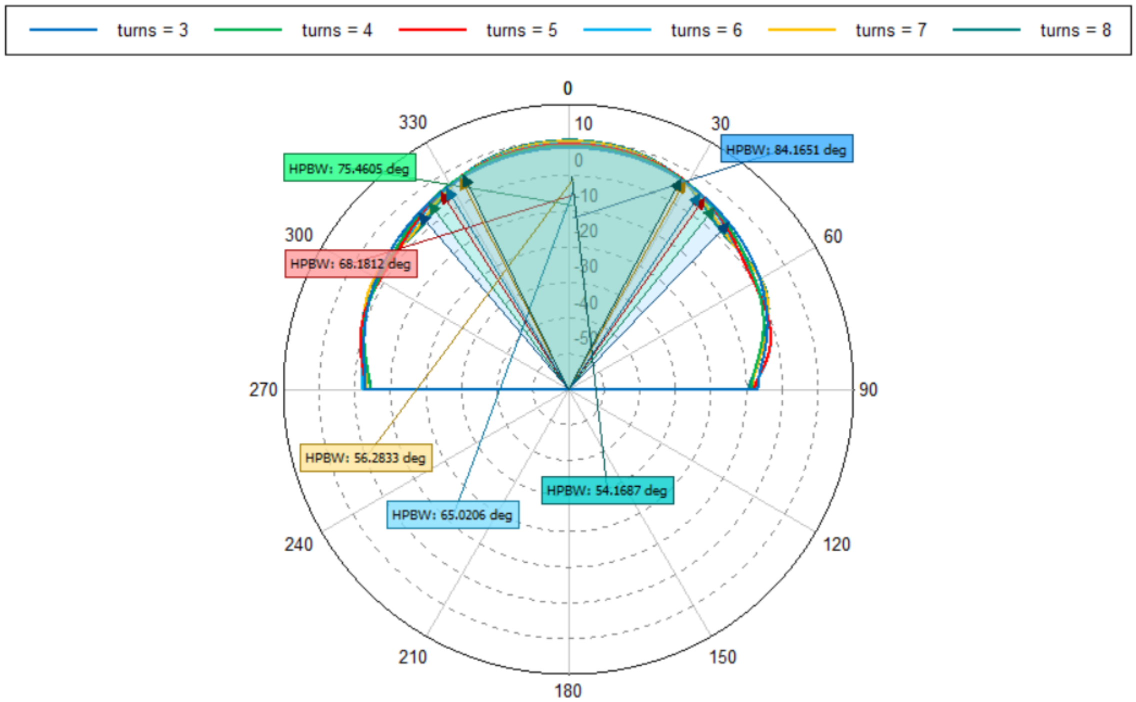


Figure 2: The HPBW of the helical antenna as the number of turns increases.

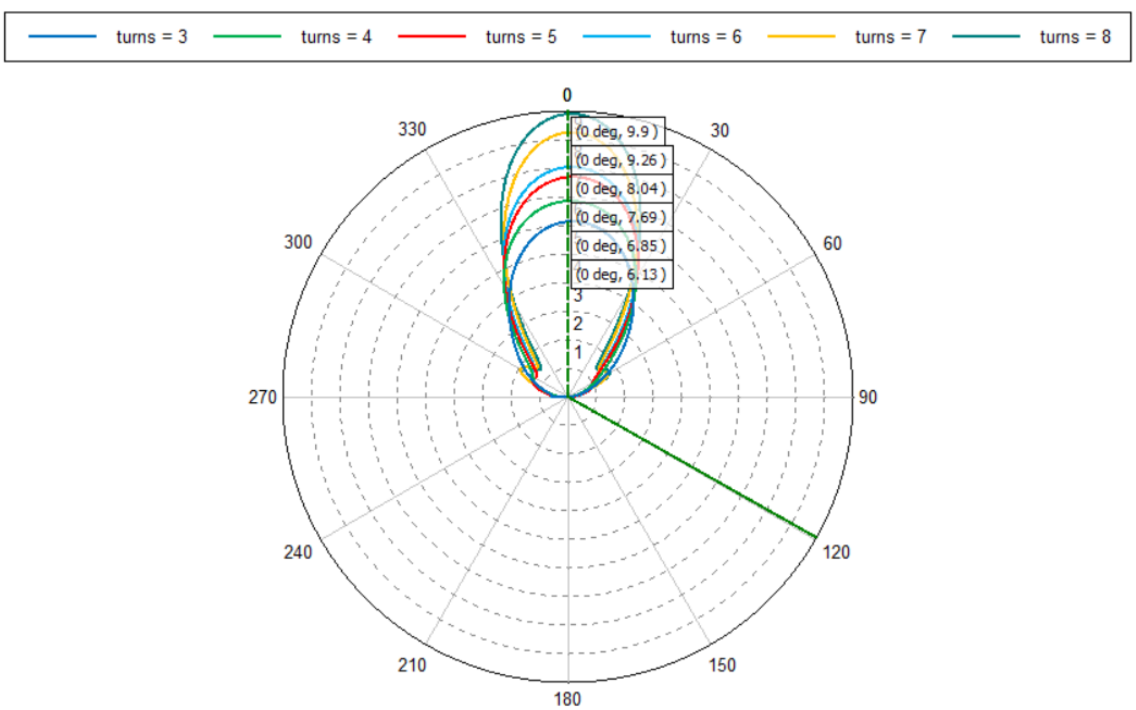


Figure 3: Directivity of the helical antenna for different turns.

As we can see from Figure 3 as the number of turns increases, the helical antenna becomes more directive. Not only does its maximum directivity increases, but the HPBW also decreases. Further more, if we look at the linearized radiation patterns, side lobes start to appear after 6 turns. Aside from this, we also compare the axial ratio for the different turns. Helical antennas are circularly polarized in bore-sight, so ideally their axial ratio (minor/major) should be $0dBi$. Axial ratio of the helical antenna in bore-sight for different number of turns is shown in 4.

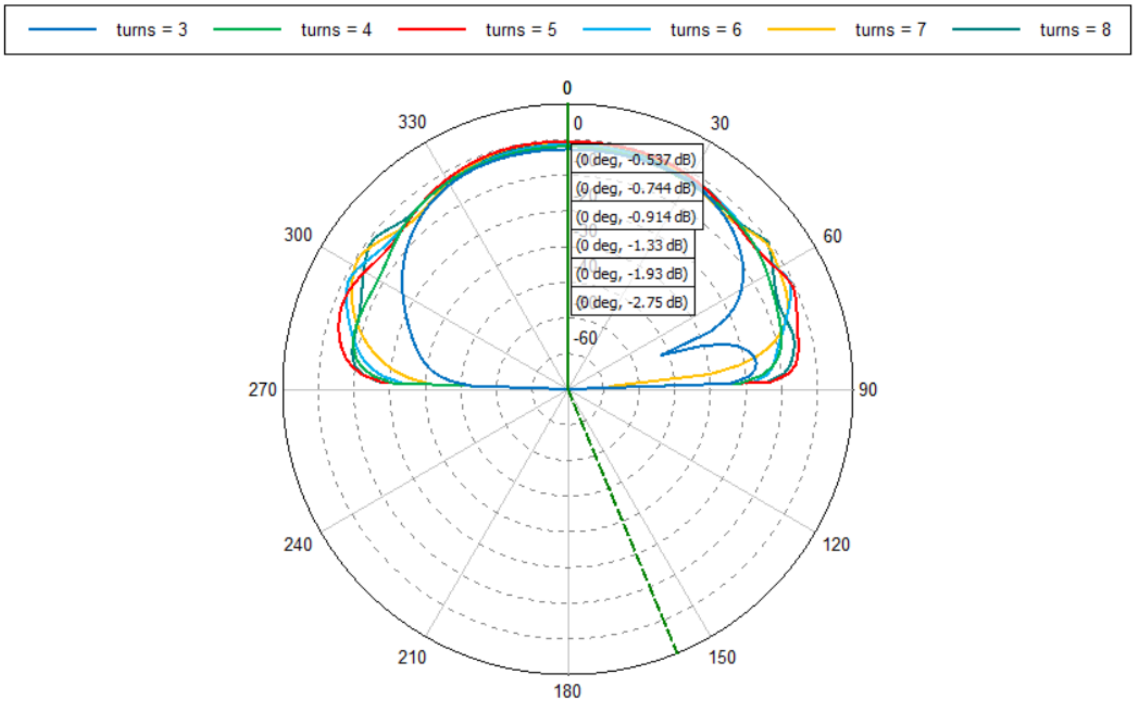


Figure 4: Axial ratio (minor/major) of the helical antenna for different number of wire turns.

All the results from the above plot are tabulated below.

Turns	**Max. Directivity**	**HPBW**(°)	**Axial Ratio**(dB)
3	6.13	84.17	−2.75
4	6.85	75.46	−1.93
5	7.69	68.18	−0.54
6	8.04	65.02	−1.33
7	9.26	56.28	−0.74
8	9.90	54.17	−0.91

Table 1: Simulation results.

If we look table, it is once more clear that as the number of turns increases, the maximum directivity increases, and the HPBW becomes narrower. As for the axial ratio, while it does fluctuate, in general it does get closer to $0dB$, implying that the helical antenna gets more circularly polarized as the number of turns is increased. It should be noted that the fluctuation in axial ratio primarily occurs due to the radius selection of the antenna (perhaps selecting a different radius would have caused less fluctuations).

Additionally, just for design verification purposes, the trend in maximum directivity across the frequency sweep from 1GHz to 2GHz for different number of turns on the helical antenna is shown in Figure 5. The plot further illustrates that increasing the number of turns leads to higher overall directivity across the frequency range, especially after 1.4GHz.

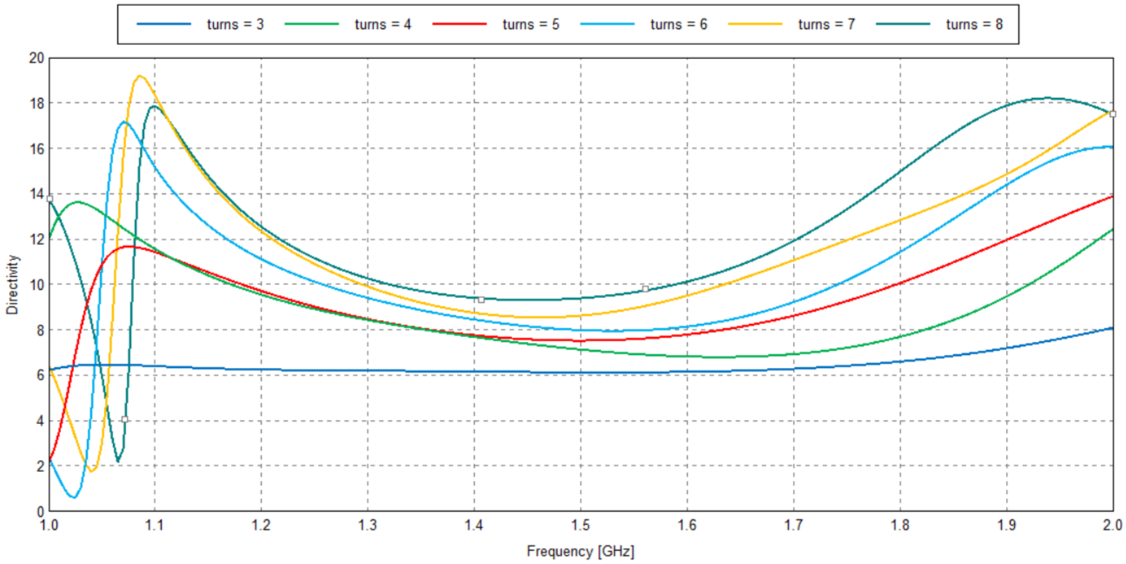


Figure 5: Trend in maximum directivity across the frequency range for the different number of turns.

1.2 (b)

In this part of the problem, the helical antenna with 4 turns is placed on the finite PEC plane as shown in 6. The GPS L1 band frequency (1.57542GHz) is chosen for operation, just like in the previous problem. In FEKO, the parametric sweep feature is used to vary the radius of the circular ground plane from 0.3λ to 3λ. The impedance of the helical antenna at 1.57542GHz is plotted as a function of the radius of the ground plane as illustrated in 7.

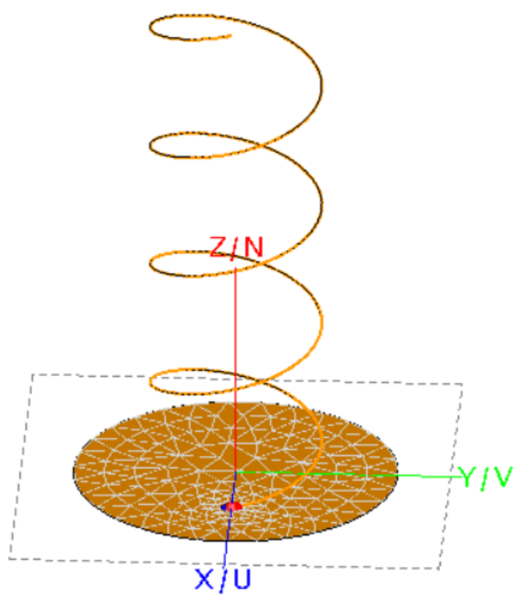


Figure 6: Helical antenna on the finite PEC ground.

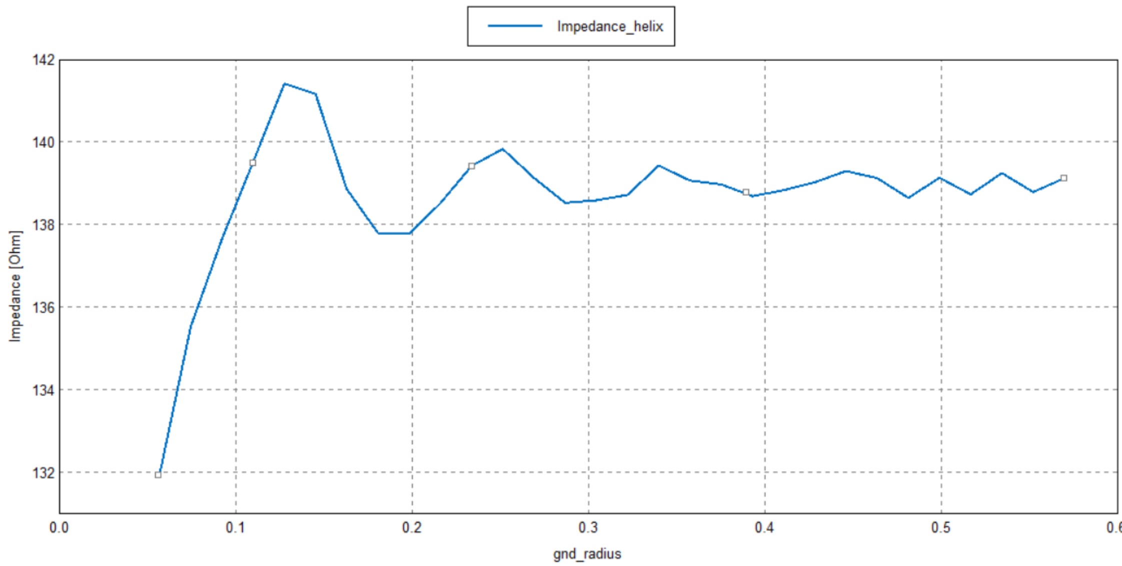


Figure 7: Impedance of the helical antenna as the radius of the finite PEC ground increases (unit for horizontal axis is meters).

From the above graph, we can see that as the radius of the ground plane continues to increase, the impedance of the antenna eventually converges to approximately 139Ω. Through the simulation we observe that the optimal size of the ground plane is approximately 0.411m. At this distance, the maximum directivity is of the helical antenna is $6.96dBi$, which we can observe in 8. This result is very close to the infinite ground case, where for $n = 4$ the maximum directivity is $6.85dBi$. Thus, the circular PEC ground plane has an optimum size at radius 0.411m.

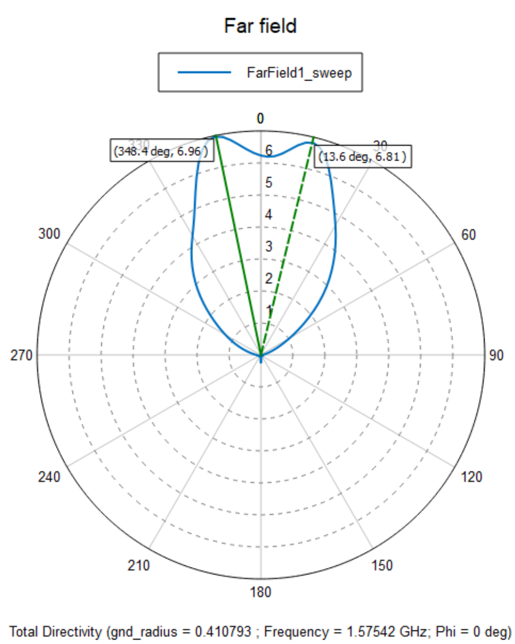


Figure 8: Radiation pattern of the helical antenna at optimum radius.

We can notice that the radiation pattern in the above image is not quite symmetric, this occurs due to the edge diffractions of the finite ground plane. For better comparison we can refer to the following table.

Finite Ground Radius (m)	Infinite PEC	Finite PEC ground
0.411	6.85	6.96

Table 2: Comparison of maximum directivity of infinite and finite PEC ground.

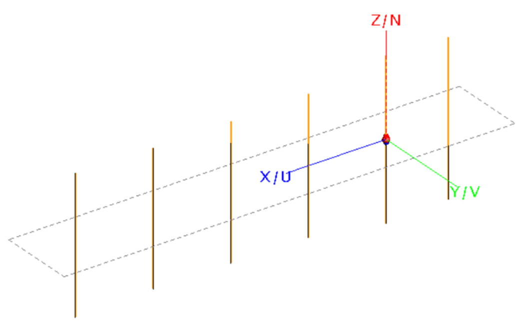
Hence, we can confidently say that the optimum radius for the finite PEC ground is 0.411m, this is where the results converge.

2 Problem 2

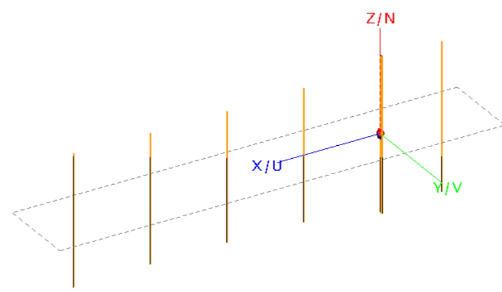
2.1 (a)

The Yagi-Uda antenna is made using Table 10.6 from the text book. In the table, element lengths from the third column is used. Since the GPS L1 band frequency, as in the previous problem, is used, the wavelength (λ) is 0.19m. The driver length is selected to be 0.5λ. The space between the directors is selected to be 0.25λ. As for the space between the reflector and driver, it is 0.2λ. The diameter of the dipoles, d, is such that $\frac{d}{\lambda} = 0.0085$. The design of the Yagi-Uda in FEKO is shown in Figure 9.

At first, we design the normal Yagi-Uda antenna. Then as requested by the problem, we design the same antenna, but this time the driver is a folded dipole. This folded dipole has arm lengths of 0.5λ and the gap between the arms is 2mm. Design of both Yagi-Udas are shown in Figure 9.



(a) Normal Yagi-Uda antenna.



(b) Yagi-Uda antenna with folded dipole at the driver.

Figure 9: Yagi-Uda antenna designs in FEKO.

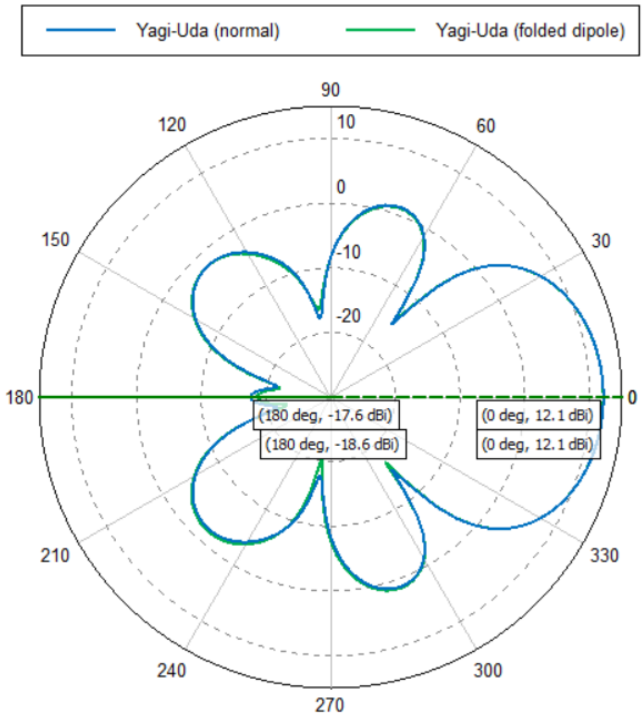


Figure 10: Radiation pattern of the two types of Yagi-Uda antennas at $\theta = 90°$ cut.

We can validate our antenna designs by looking at the maximum directivity of both antennas. Ideally, for a Yagi-Uda with 4 directors, the maximum directivity should be 10.2dB. From 10, we can see that the maximum directivity of each antenna is 12.1dBi. To convert dBi to dB, we subtract 2.15. Thus, we compute $12.1 - 2.15 = 9.95$dB. This is close to 10.2dB. Therefore, we can confirm that our antenna designs are valid. When we look at the radiation patterns of these antennas, they look almost identical. However, the differences become noticeable when we look at the impedance for each type of antenna as in Figures 11 and 12. From the two plots, we can clearly see the difference in impedance trend for the two types of Yagi-Uda antennas. Not only are there changes in resonance and anti-resonance frequencies, but the antenna with the folded dipole appears to have a higher impedance than the regular antenna. If we look at Figure 13, we notice that the magnitude of the impedance for the folded dipole Yagi-Uda is N^2 higher than the normal Yagi-Uda, where N is the number of arms on the folded dipole. For example, at 1.5GHz, the normal Yagi-Uda has an impedance of 49.82Ω. Using this reading we can do the following computation.

$$\begin{aligned} Z_A &= N^2 Z_d && (1) \\ &= (2)^2 49.82 && (2) \\ &= 199.28 && (3) \end{aligned}$$

In the above equation, Z_d is the impedance of the normal Yagi-Uda, while Z_A is the impedance that one would expect to get from a folded dipole. The value of Z_A is 199.28Ω. This is close to the impedance for the Yagi-Uda with the folded dipole in FEKO, which at 1.5GHz is 234.7Ω.

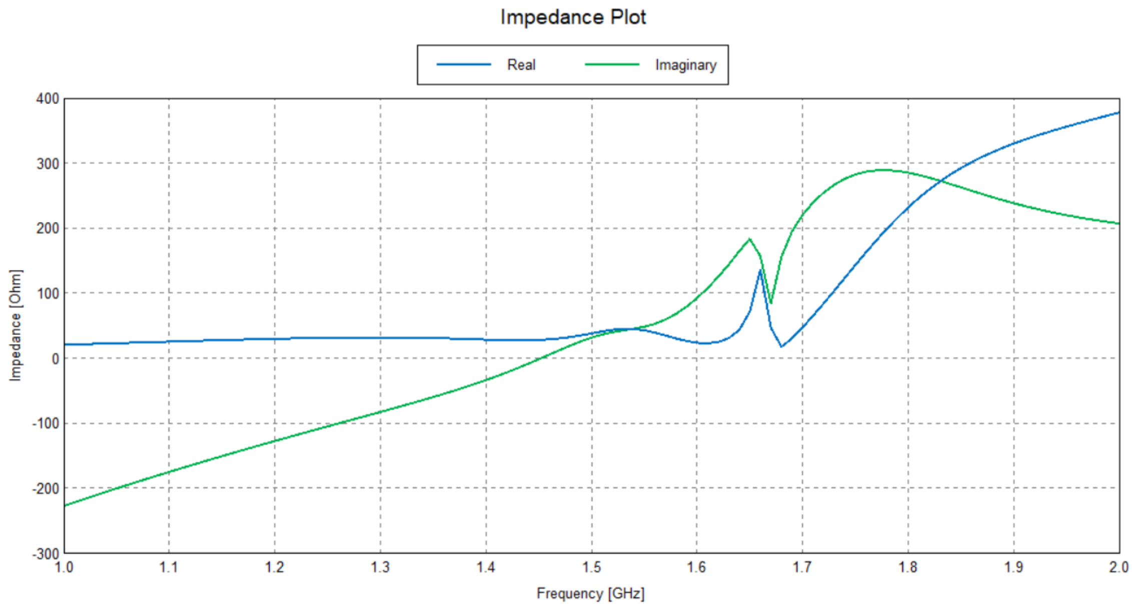


Figure 11: Impedance plot of the Yagi-Uda antenna (driver dipole is not folded).

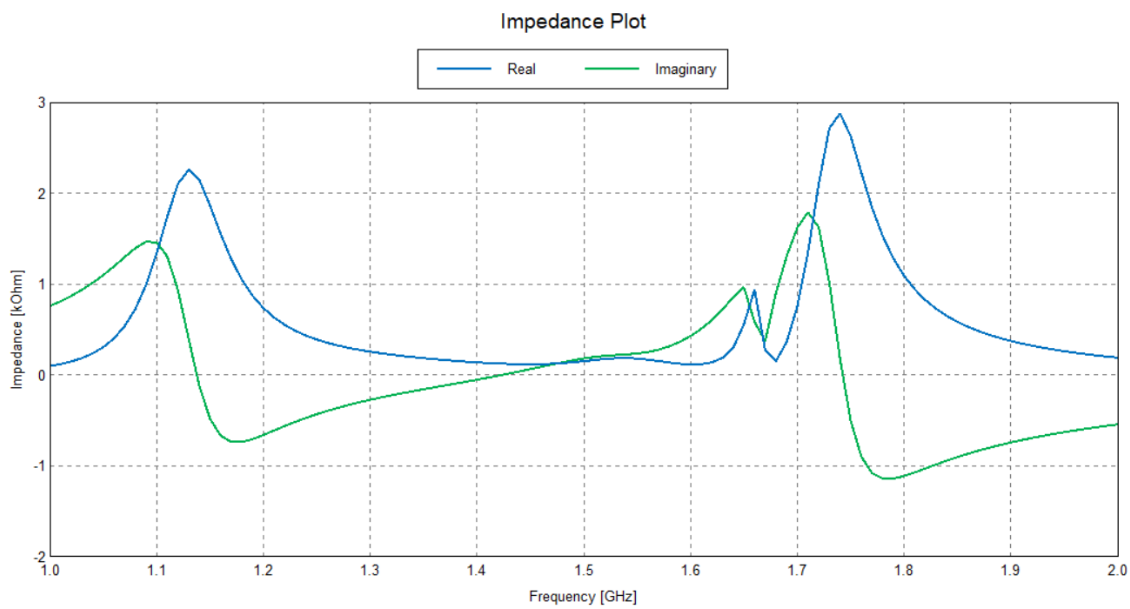


Figure 12: Impedance plot of the Yagi-Uda antenna with the folded dipole driver.

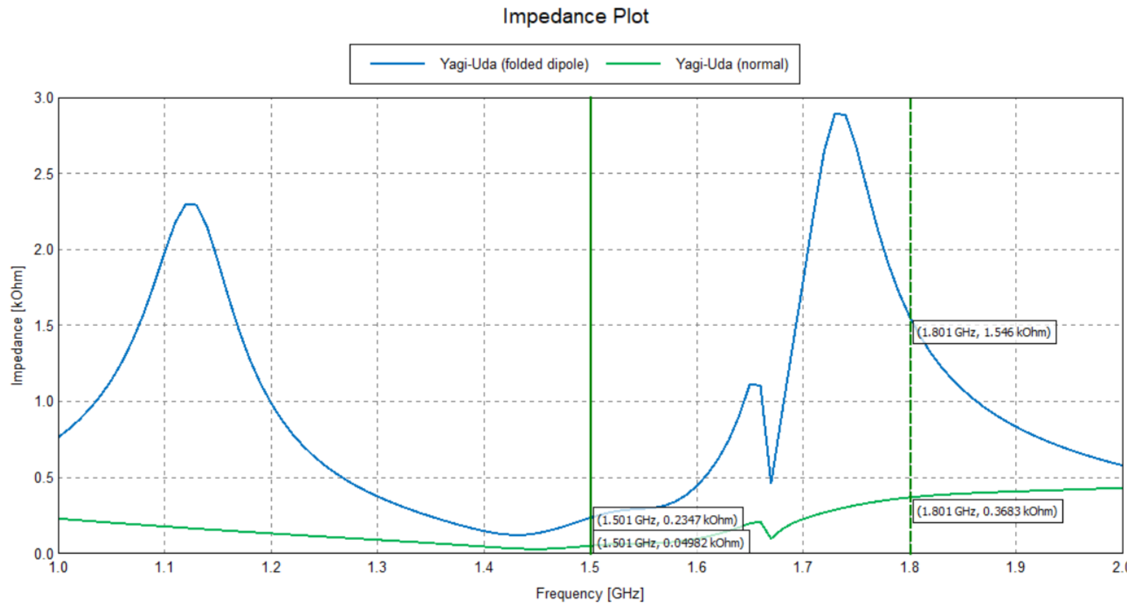


Figure 13: Comparing impedance magnitudes of the Yagi-Uda with and without the folded dipole.

2.2 (b)

For this problem, we vary the gap between the reflector and driver of the Yagi-Uda from the previous problem using the parametric sweep feature in FEKO. The sweep is done from approximately 0.3λ to 0.6λ. We attempt the generate a plot similar to the one shown in slide 39.

In Figure 14 we show that the gain of the Yagi-Uda as a function of the space between the driver and the reflector. Based on the following figure, we can say that the optimal distance between the driver and reflector (behind the driver) should be approximately 4.87cm. At this distance, a maximum gain of 12.07dBi is achieved.

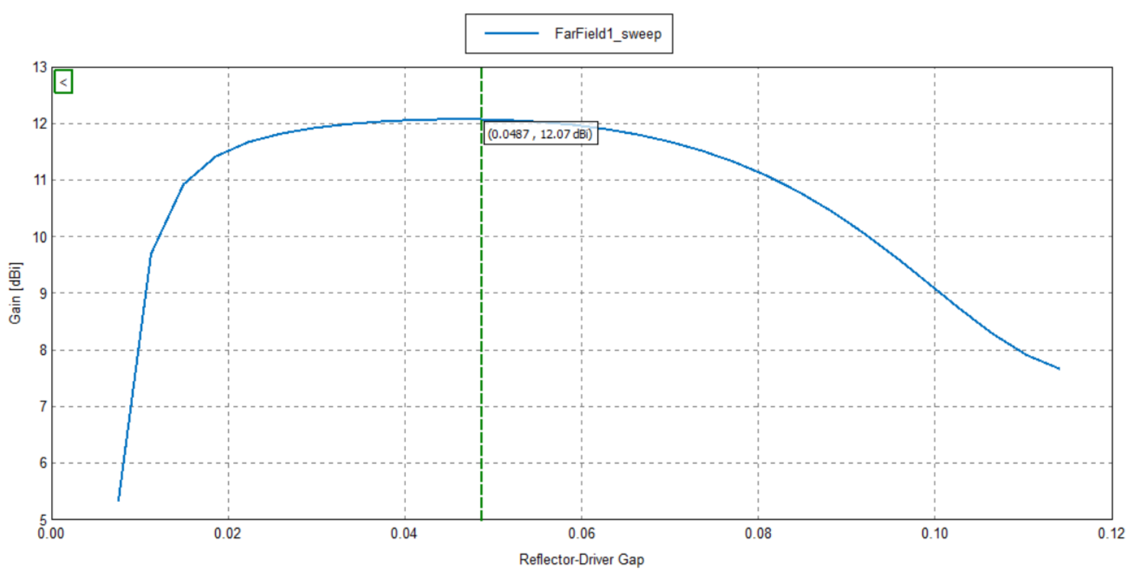


Figure 14: Maximum Gain of the Yagi-Uda as a function of the gap between the reflector and the driver at $\theta = 90°$ and $\phi = 0°$ (note that the horizontal axis is in meters).