ECEN5134 Homework 3

Labib Sharrar

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1 Solutions

1.1 (a) Length of Dipole

The physical length at which the dipole reaches resonance at $150MHz$ is $0.95m$. The complex impedance of the dipole at resonant frequency is $72.4 + j2.1$. This becomes evident when we look at the impedance plot for a single dipole in FEKO.

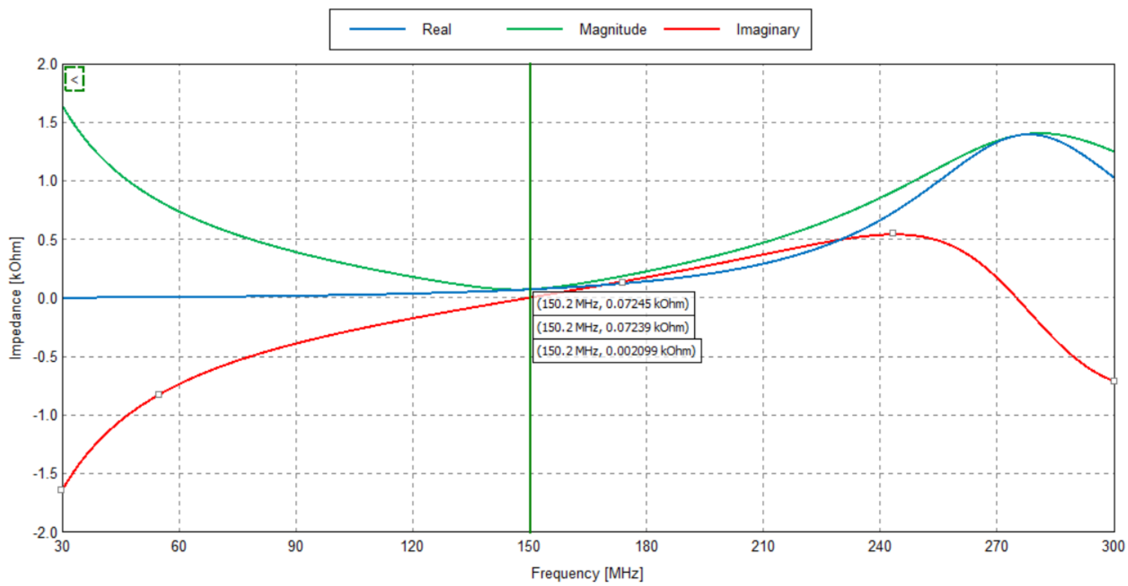


Figure 1: Impedance plot across multiple frequencies in FEKO.

1.2 (b) Effect on the dipoles

After designing the cross-dipole as instructed in the previous problem, we try to find out if they affect each other by two experimental cases. In the first case, we excite just one of the dipoles and record the impedance values at different frequencies (between $30MHz$ and $300MHz$). In the second case, both dipoles are excited and we record the same parameters. Readings from the two experimental cases are recorded in the following table.

Frequency (MHz)	Impedance (1 dipole excited)	Impedance (2 dipoles excited)
30	$1.69 – j1650$	$1.693 – j1646$
75	$11.64 – j537.6$	$11.6 – j538$
100	$23 – j311$	$23.02 – j311$
150	$72 + j0.46$	$72 + j0.46$
225	$469.4 + j436$	$469.4 + j436$
300	$1028 – j711.5$	$1028 – j711.5$

Table 1: Impedance at different frequencies for the two cases.

As we can see, the readings from case 1 and case 2 are identical, implying that the dipoles do not affect each other. A reason for this is that we have vertically polarized dipole and a horizontally polarized one. The electromagnetic (EM) waves from the dipoles are perpendicular to each other. The dipoles would have affected each other if there was mutual coupling. However, this only happens if there is a tangential component of the electric field vector along the dipole conductor. As the EM waves are orthogonal to one another, there is no tangential component of the incident wave acting on either dipole. Thus, due to this cross polarization orientation, the incident waves from either dipole do not have much effect on the charge particles of the other. Nevertheless, the radiation pattern of the cross-dipole is indeed different from that of a regular dipole, as shown in the following figure.

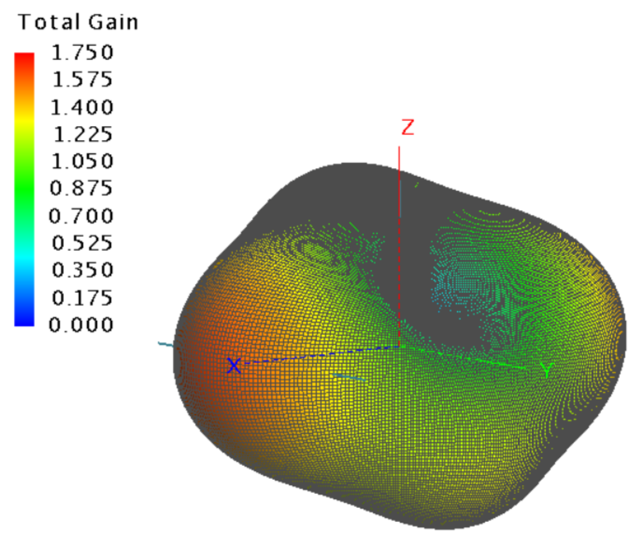


Figure 2: The three dimensional gain pattern (not in dB) of the cross-dipole.

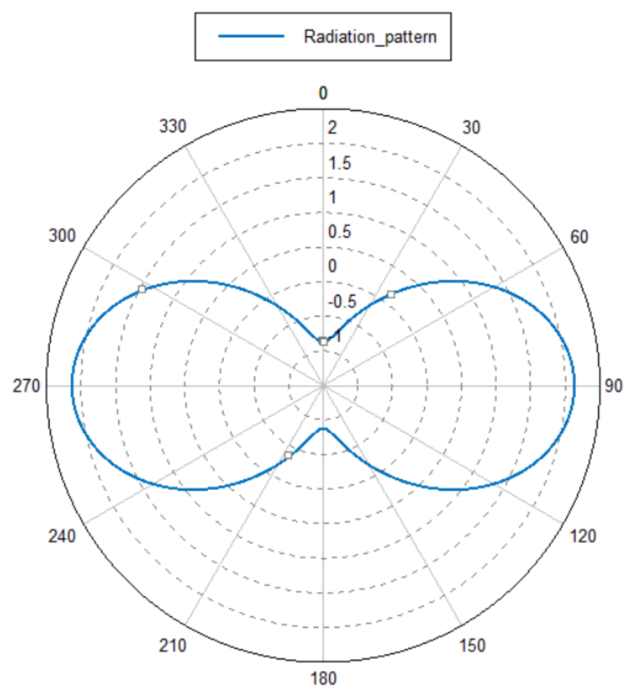


Figure 3: The gain pattern at $\phi = 0°$ cut at resonant frequency.

1.3 (c) Cross-dipole Radiation Pattern

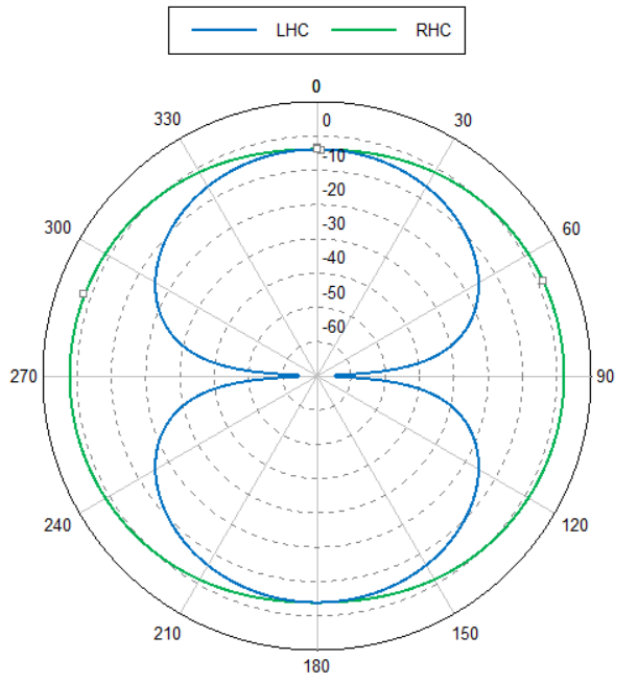


Figure 4: The LHC and RHC plot at $\phi = 0°$ cut.

From the above figure, we can see that the RHC polarization (RHCP) mostly dominates the LHC at $\phi = 0°$ cut. The LHC polarization (LHCP) only seems to become slightly dominant around $\theta = 0°$ and $\theta = 180°$. The RHCP (green) exhibits a nearly omnidirectional pattern, indicating that the antenna primarily radiates in right-hand circular polarization, while the LHCP (blue) forms a donut cross section with nulls in the direction of $\theta = 90°$ and $\theta = 270°$, suggesting significant suppression of the cross-polarization component. A reason for this is the way the horizontally and vertically polarized dipoles are arranged. For further details, we can refer to the dipole arrangement in the following figure.

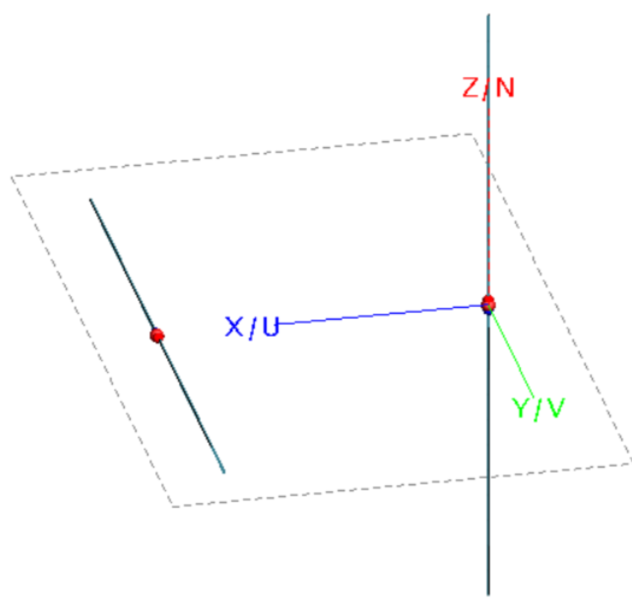


Figure 5: The 3D model showing the arrangement of the dipoles.

The vertically polarized dipole is placed at coordinates $(x = 0, y = 0, z = 0)$ with current flowing in positive z direction. As for the horizontally polarized one, it is placed at $x = 0.5m, y = 0, z = 0$ with current flowing from $-y$ to $+y$ direction. Furthermore, the dipoles are separated by $50cm$, which is a quarter wavelength distance. So there will be a 90° phase difference between the waves from the two dipoles. This results in circular polarized wave. At the $\phi = 0°$ cut, the RHCP is dominant since the vertical component of the electric field, which we can refer to as E_y lags $\phi = 0°$ behind the horizontal component E_x. This is also the case, because the horizontally polarized dipole is placed in positive x direction. Placing it at negative x would have made LHCP dominant. The direction of current flow in each dipole is also responsible for RHCP dominating.

1.4 (d) Maximum and Minimum Polarization Losses

As shown in the previous subsection, the RHC polarization is dominant, so we measure its HPBW as follows:

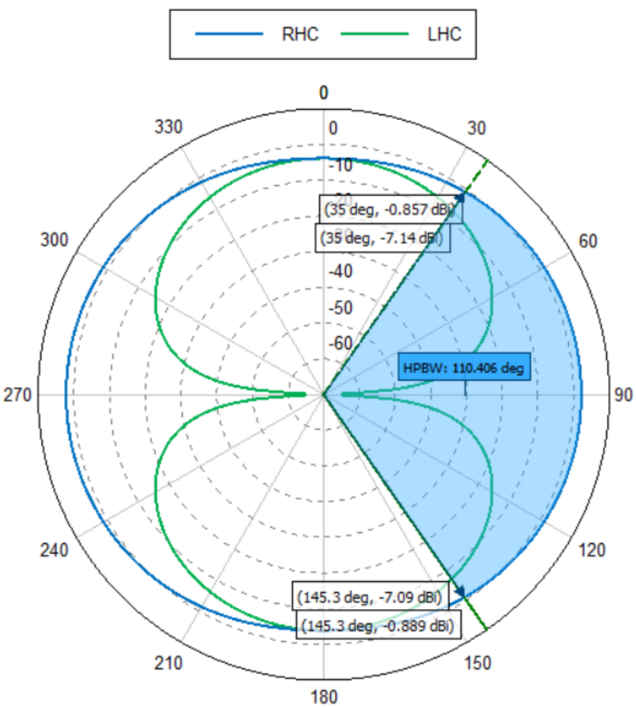


Figure 6: The HPBW of the RHC polarized gain pattern.

From the above figure we can see that the HPBW is 110.41°. In the first quadrant of the polar plot, the HPBW arc begins at approximately $\theta = 35°$. We use this reading to answer the question in this subsection.

Let us now say that the cross-dipole is used to communicate with a vertically polarized dipole placed far-away in the –x direction within the HPBW arc. To find the maximum and minimum polarization losses, we first build the axial ratio plot in FEKO, with *Major/Minor* and then take the axial ratio reading at $\theta = 35°$.

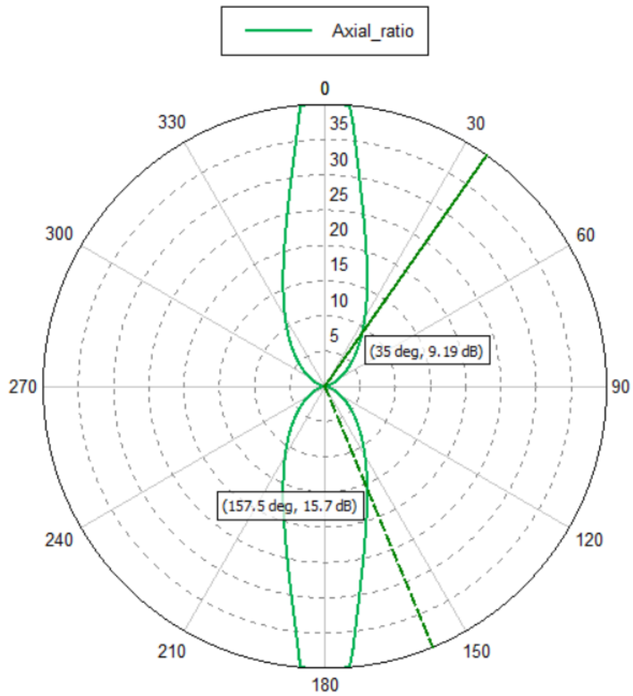


Figure 7: The axial ration plot.

At $\theta = 35°$ the axial ratio is $9.19dB$. Now that we have obtained this reading, we use the nomogram to find the maximum and minimum polarization losses. It should be noted that while cross-dipole setup has losses, the imaginary vertically polarized dipole along the $-x$ direction is lossless. As such, its axial ratio is considered to be $40dB$. The nomogram plot is shown below. It should be noted that $\theta = 90°$ at $\phi = 0°$ cut is also within HPWB. The axial ratio at this direction is $0dB$. Therefore, we also compute the maximum and minimum polarization losses for this part.

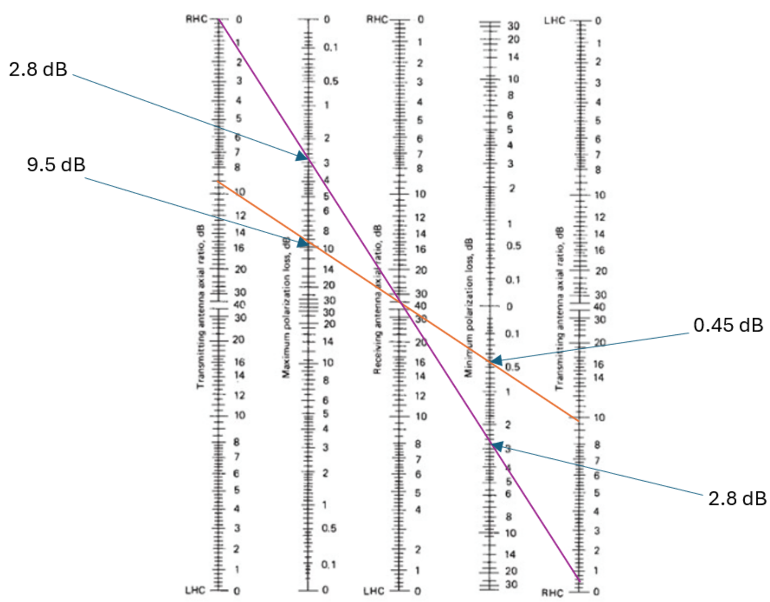


Figure 8: Readings from the nomogram plot.

Based on the above figure the maximum and minimum polarization loss readings are given in the table below.

Angle within HPBW	Maximum Loss (dB)	Minimum Loss (dB)
$\phi = 0°$ and $\theta = 35°$	9.5	0.45
$\phi = 0°$ and $\theta = 90°$	2.8	2.8

Table 2: Impedance at different frequencies for the two cases.

From the above table, we can see that the **maximum** polarization loss can be **9.5dB** while the **minimum** polarization loss goes down to approximately **0.45dB**.

1.5 (e) Maximum Effective Area of the Cross-dipole)

To compute the maximum effective area (A_{em}) of the cross-dipole, we use the following formula.

$$A_{em} = \frac{\lambda^2}{4\pi} \times G_0 \tag{1}$$

In the above equation G_0 is the maximum gain and since the resonant frequency is $150MHz$, the wavelength is $2m$. The maximum gain computed in FEKO is $2.13dB$ or 1.63 in magnitude. Thus, we can do the following calculation.

$$A_{em} = \frac{\lambda^2}{4\pi} \times G_0 \tag{2}$$

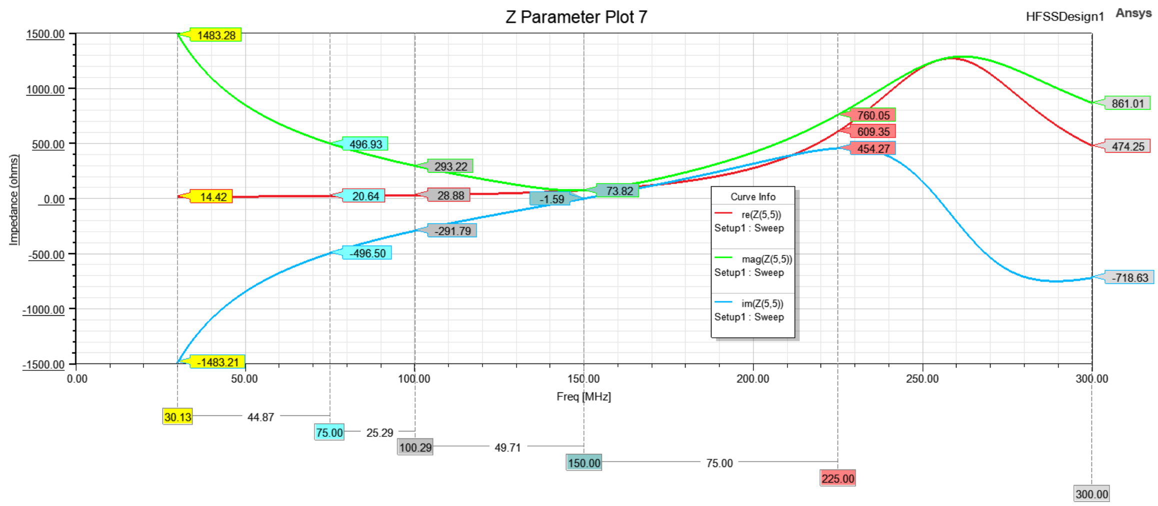
$$A_{em} = \frac{2^2}{4\pi} \times 1.63 \tag{3}$$

$$A_{em} = 0.52 \tag{4}$$

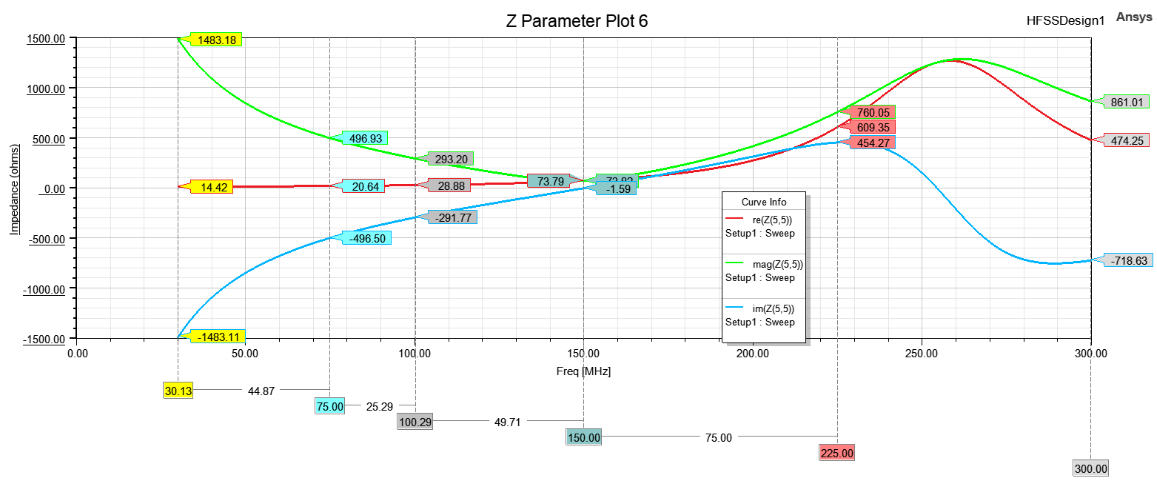
Thus, the maximum effective area is **0.52**.

1.6 (f) Repeating (b) with HFSS Simulations

We repeat the steps in (a) in HFSS. After designing the dipoles, we carry out two different simulations. One with a single dipole activated and the other with both dipoles activated. The impedance plots from the two experimental cases are provided below.



(a) One dipole excited.



(b) Two dipoles excited.

Figure 9: Impedance plots in HFSS for the two experiments.

The impedance readings from HFSS for the two experimental cases are given below.

Frequency (MHz)	**Impedance (1 dipole excited)**	**Impedance (2 dipoles excited)**
30	14.42–j1483.21	14.42–j1483.11
75	20.64–j496.50	20.64–j496.50
100	28.88–j291.79	28.88–j291.77
150	$73.82 - j1.59$	$73.79 - j1.59$
225	$609.35 + j454.27$	$609.35 + j454.27$
300	474.25–j718.63	474.25–j718.63

Table 3: Impedance at different frequencies for the two experimental cases in HFSS.

Like we found for FEKO, in HFSS regardless of whether one or both dipoles are excited, the impedance of each dipole remains the same. This is evident when we look at the above table. Thus, the dipoles have negligible effect on each other. The reason for this has already been provided in (b). Also similar to what we found in FEKO, while the impedance of the dipoles are not affected, the overall radiation pattern does change as shown in the plot below.

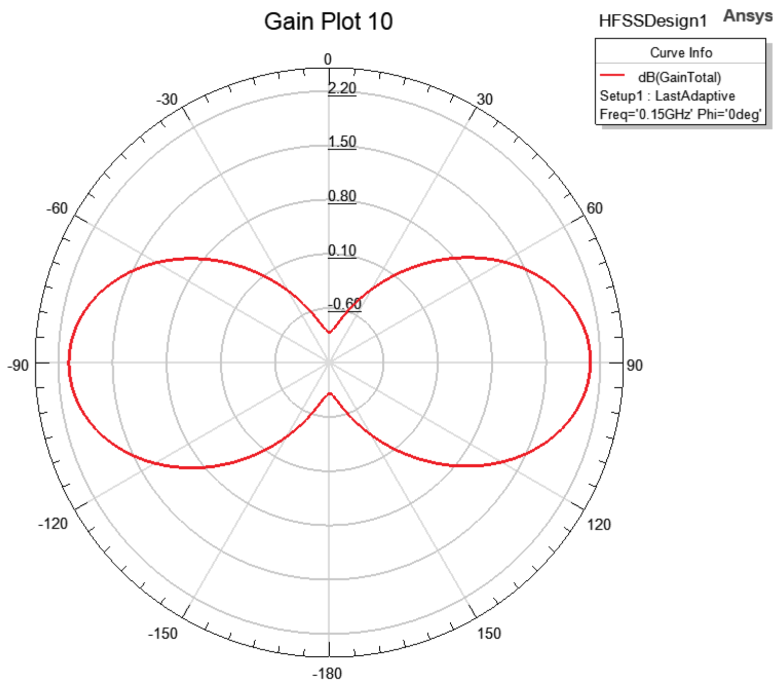


Figure 10: Gain pattern at $\phi = 0°$ cut at resonant frequency in HFSS.

Hence, we can confidently say that our results from FEKO and HFSS are equivalent.