ECEN5134 Homework 9

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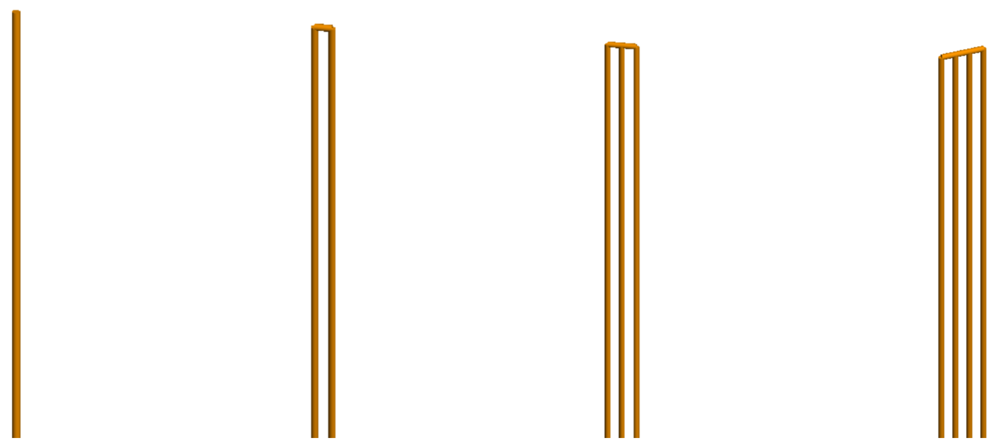
1 Problem 1

For this problem, we simulate folded monopoles in FEKO for different number of arms: $n = 1, 2, 3, 4$. The monopole arms are a quarter wavelength in length. Since we select the operating frequency to be 150MHz, the length of the folded monopole arms are 0.5m. As for the wire radius of the monopole, it is 1×10^{-5}m. Spacing between the arms is $0.00005m$. We attempted to make the spacing between the arms as small as possible to ensure the validity of equation 1. Finally, it should be noted that the folded monopole is simulated over an infinite PEC ground plane. The example of the model is shown below.



(a) $N = 1$ (b) $N = 2$ (c) $N = 3$ (d) $N = 4$

Figure 1: Folded monopole models simulated in FEKO.

Folded monopoles with different number of arms are simulated in separate CADFEKO files. The input impedance for the each of these models are determine using the formula given in Slide 19, which is as follows:

$$Z_A = N^2 Z_m \tag{1}$$

In the above equation, Z_m is the impedance of a quarter wavelength monopole, which is approximately $36.5 + j21.25$ (we convert this to magnitude). We denote the overall impedance of the folded monopole and the number of arms as Z_A and N. The variable Z_A is used as input impedance for each model. These are computed as follows:

$$Z_A = (1)^2|Z_m| = (1)^2|42.23| = 42.23 \tag{2}$$
$$Z_A = (2)^2|Z_m| = (2)^2|42.23| = 168.92 \tag{3}$$
$$Z_A = (3)^2|Z_m| = (3)^2|42.23| = 380.07 \tag{4}$$
$$Z_A = (4)^2|Z_m| = (4)^2|42.23| = 675.68 \tag{5}$$

The VSWR plots for each model is illustrated in Figure 2 and in Figure 3 we have impedance trend of the monopole for different number of arms.

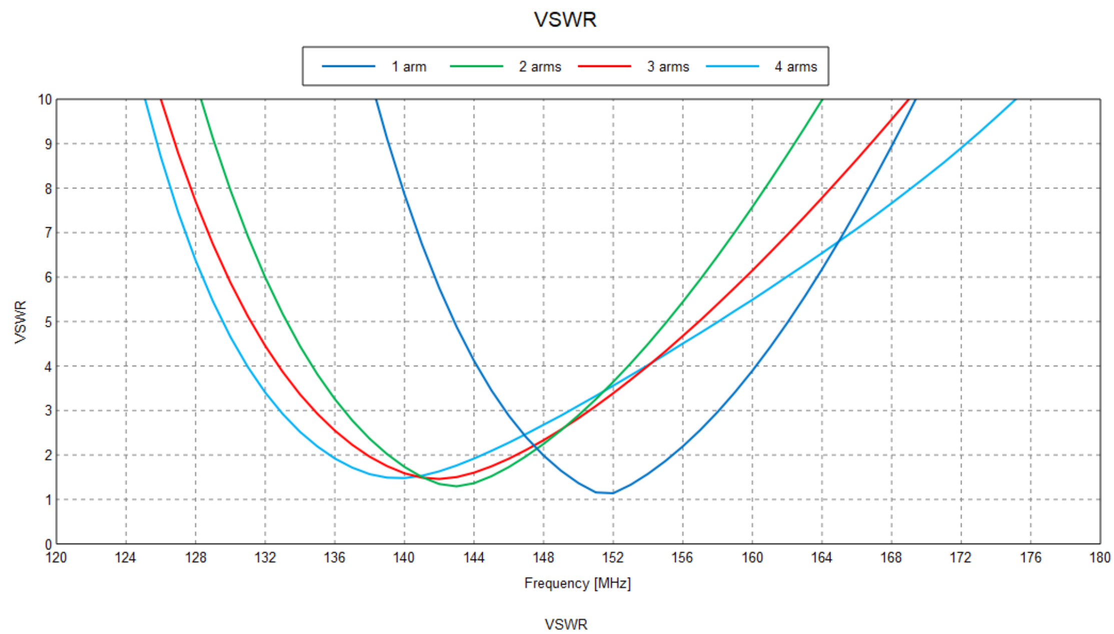


Figure 2: VSWR as a function of frequency for folded monopoles of different arm numbers.

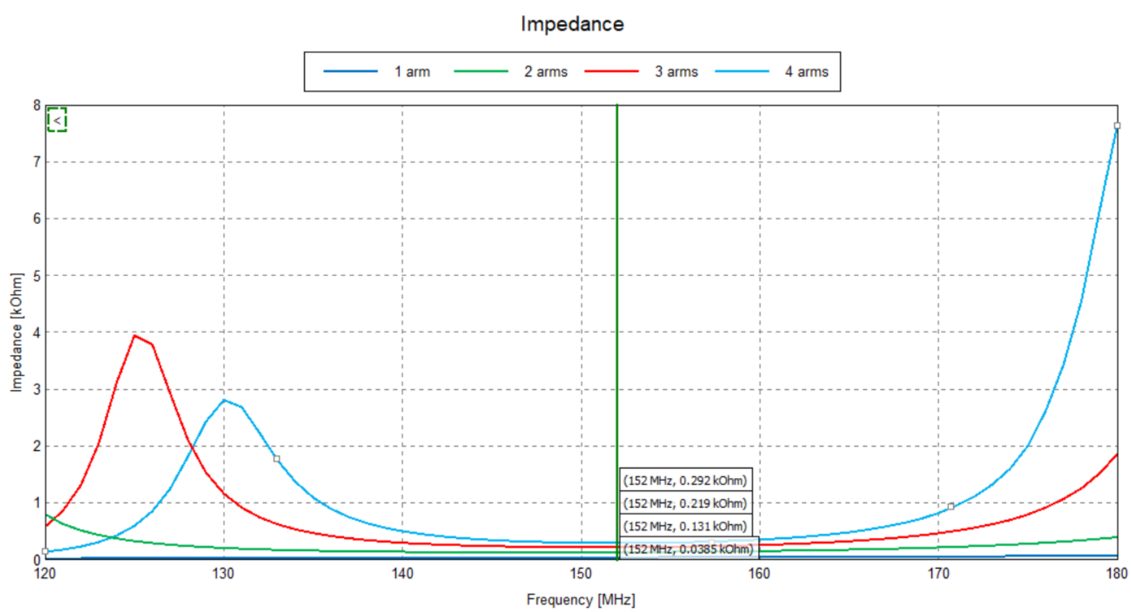


Figure 3: Impedance trend of the folded monopole with different number of arms.

Using the plot above, we try to compute the bandwidth for VSWR below 2, for each model. Aside from this, to select the validity of our simulation, **we check the impedance values at the resonant frequency for a single arm monopole, which is approximately** 152**MHz** (as instructed during office hours). Detailed results from the FEKO simulation are shown in the following table.

No. Arms	Nominal Impedance (Ω)	Bandwidth (MHz)	Resonant Impedance (Ω)
1	42.23	7.4	38.5
2	168.92	8	131
3	380.07	8.5	219
4	675.68	8.7	292

Table 1: Simulation results of the folded monopole.

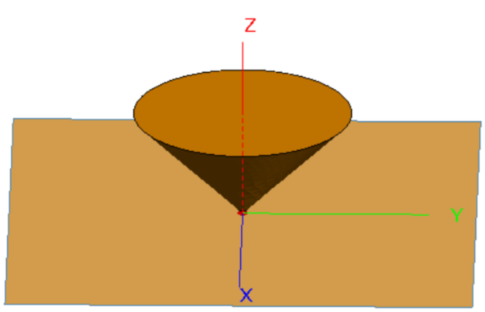
From the above table we can see that as the number of arms at the folded monopole increase, the bandwidth for VSWR below 2 also increases. While the reference impedance in POSTFEKO is selected using equation 1, the actual impedance of the folded monopole antennas do not seem to closely follow the equation, especially for $N = 3, 4$. Ideally in Table 1, the columns *Nominal Impedance* and *Resonant Impedance* should be the same. **The reason for the discrepancy is related to properties of Method of Moments, which is the primary solver used by FEKO**. Equation 1 is derived form the transmission line equation (equation 9-21 from the course textbook). The characteristic impedance of the transmission line is more accurate and agrees with the Method of Moments when the ration of the space between the wires and the wire diameter (s/d) is small. The as s/d gets larger, the transmission line model begins to disagree with the Method of Moments. So, in our case, why does the antenna impedance start to disagree with equation 1 as N increases? To answer this question, we refer to equation 9-24a from the course book which is written as follows.

$$a_e = \sqrt{as} \tag{6}$$

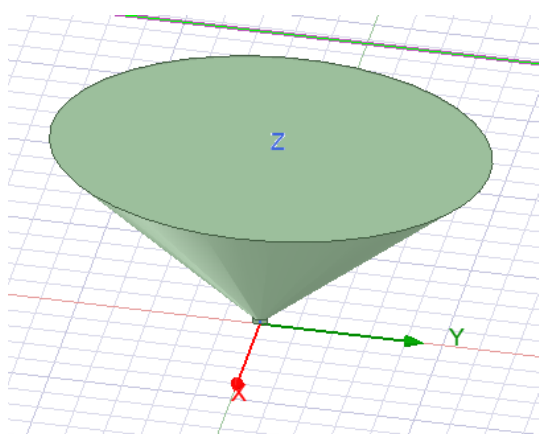
In equation 6, the a_e is the equivalent radius of the folded monopole, and a is the radius of a single arm in at the antenna. As for s, it is the spacing between the arms. As the number of arms at the folded monopole increases, the a_e increases. Since a is fixed, theoretically the variable s increases. This results in the ratio s/d getting larger as the number of arms increases. As s/d gets larger, the transmission model starts to disagree with the Method of Moments solver. Hence, this is the reason why as the number of arms increases, the nominal impedance and impedance at resonance (as shown in the table) get further from each other.

2 Problem 2

In this section, we simulate the mono-cone and attempt to reproduce the plots shown in slide 32, in both FEKO and HFSS. The center frequency we choose for the simulations is 150MHz. The mono-cone is constructed using the parameters given in slide 32. We simulate the mono-cone from 20MHz to 750MHz. Since the center frequency is 150MHz and $\lambda = 2$. So, the height of the mono-cone is 0.5m. The base radius is $\lambda_{min}/20$ and the top cone radius is $\lambda_{min}/20 + (0.5 \times tan(45°))$.



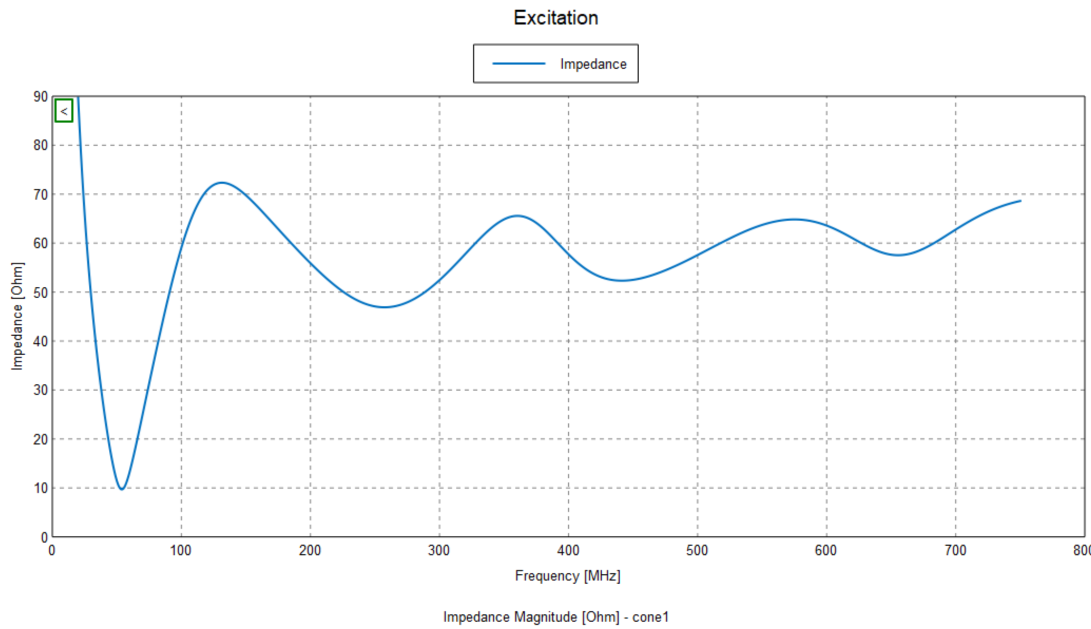
(a) The mono-cone in FEKO



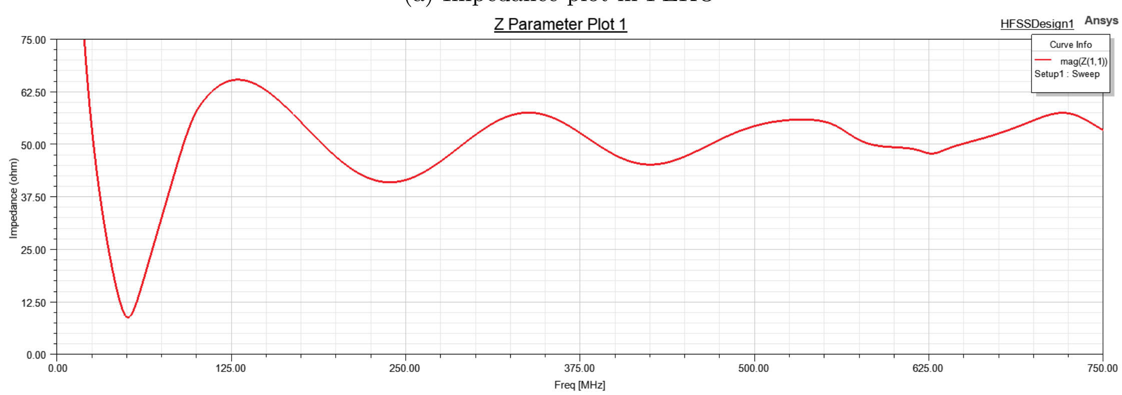
(b) The mono-cone in HFSS

Figure 4: Mono-cone over infinite PEC ground.

For this problem we also need to compare the simulated impedance of the mono-cones in FEKO and HFSS to the analytical solution, which uses the formula $Z_{in} = \frac{\eta}{\pi} \ln\left[\cot\left(\frac{\alpha}{4}\right)\right]$. Since we are dealing with a mono-cone, the output of the equation is divided by 2. The impedance plots from FEKO and HFSS are shown below.



(a) Impedance plot in FEKO



(b) Impedance plot in HFSS

Figure 5: Impedance plots of the mono-cone.

In FEKO, the impedance eventually converges to approximately 55Ω and in HFSS, the impedance converges to approximately 51Ω. These values are close to the analytical impedance solution, which is computed as follows (for the computation we select $\alpha = 90°$ as shown in slide 32).

$$Z_{in} = \frac{\eta}{2\pi} \ln\left[\cot\left(\frac{\alpha}{4}\right)\right] \tag{7}$$

$$Z_{in} = \frac{120\pi}{2\pi} \ln\left[\cot\left(\frac{90}{4}\right)\right] \tag{8}$$

$$Z_{in} = 60 \ln\left[\cot\left(22.5\right)\right] \tag{9}$$

$$Z_{in} = 52.88 \tag{10}$$

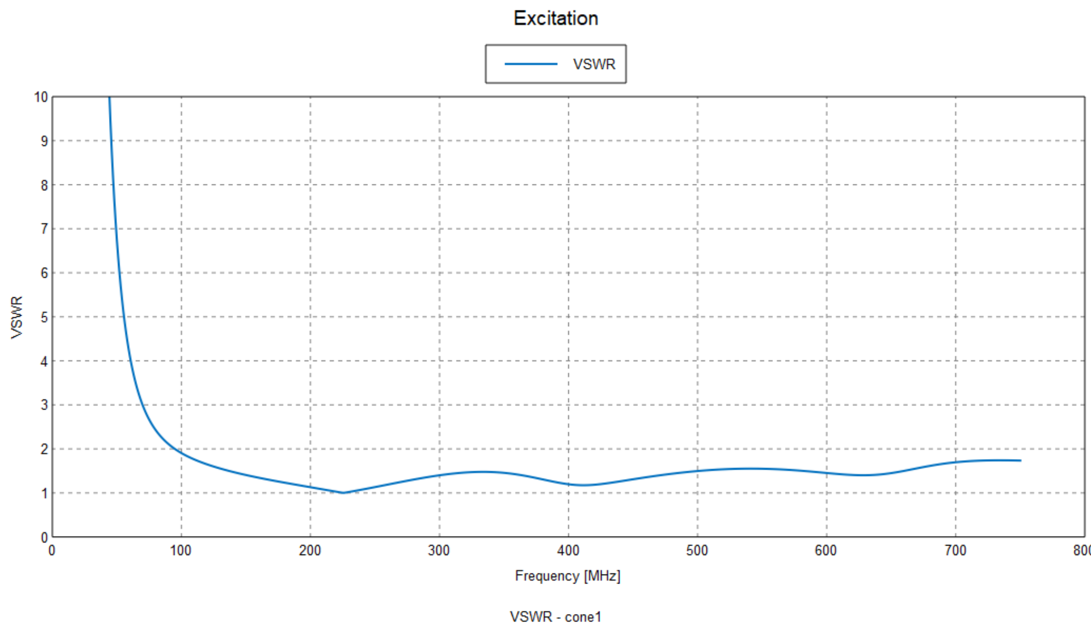
For comparison purposes, the impedances are tabulated below.

Impedance in FEKO (Ω)	Impedance in HFSS (Ω)	Analytical Impedance (Ω)
55	51	52.88

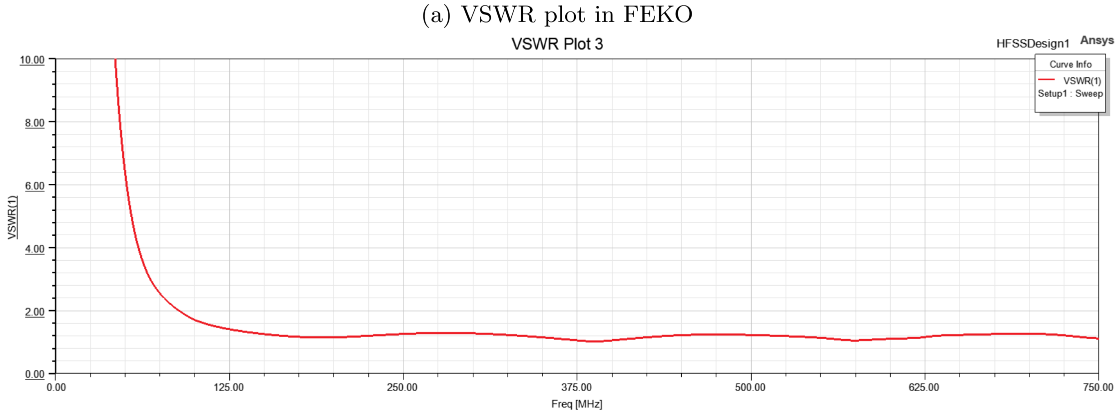
Table 2: Mono-cone impedance.

From the table above, we can see that the impedance in FEKO and HFSS are close to the impedance from the analytical solution. This proves that our simulations are valid.

We also compare the VSWR results from both FEKO and HFSS as well as the radiation patterns as shown in Figures 6 and 7.

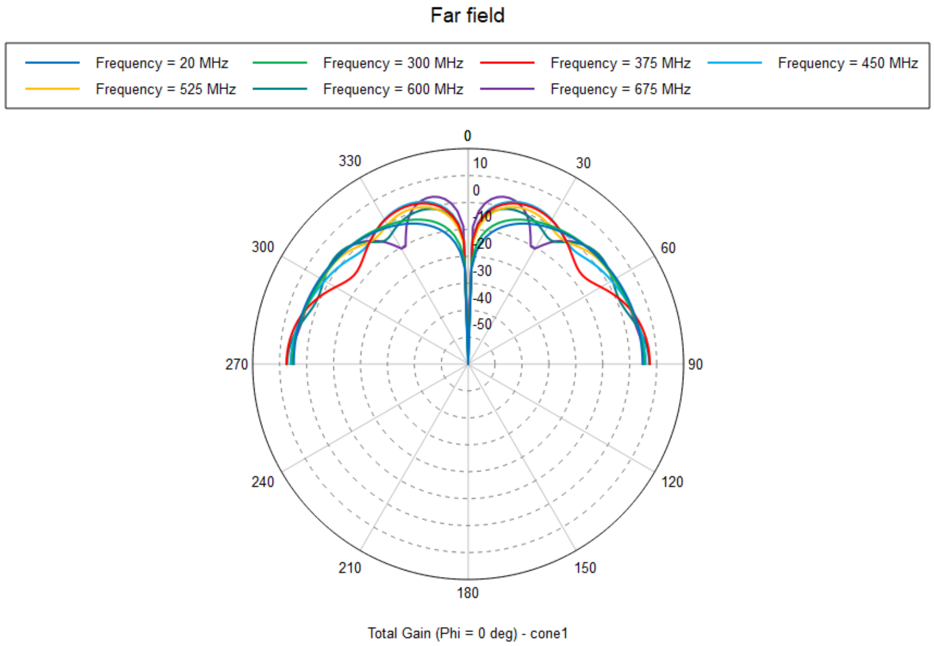


(a) VSWR plot in FEKO

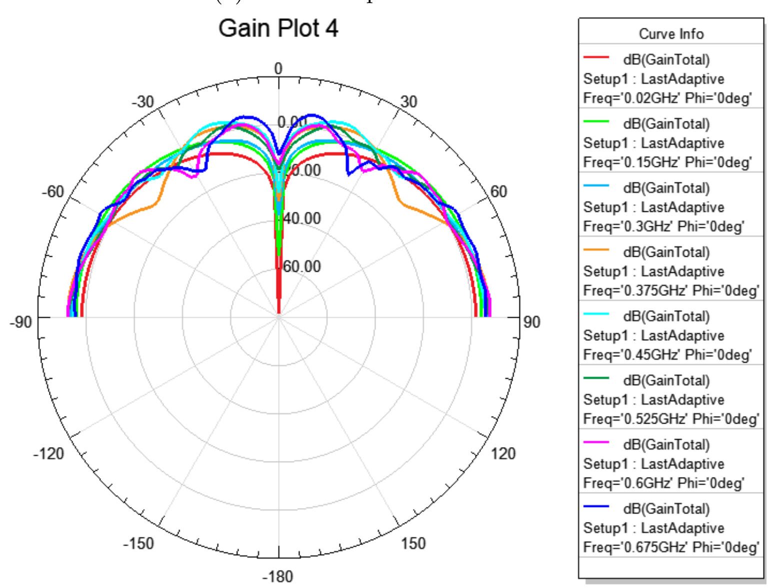


(b) VSWR plot in HFSS

Figure 6: VSWR plots of the mono-cone.



(a) Radiation pattern in FEKO



(b) Radiation pattern in HFSS

Figure 7: Radiation patterns for the different frequencies illustrated in slide 32.

From Figures 6 and 7, we can observe that the VSWR and radiation patterns in both FEKO and HFSS are identical. The results from both software match the plots in slide 32.