Waveguide Design With HFSS

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EECE.4610

Engineering Electromagnetics II

Final Report

Introduction:

This lab involves the investigation of Electromagnetic waveguides. The simulation can be separated into 3 section:

1. Create a waveguide that propagates TE10 wave at 10GHz with the maximum width of the waveguide.
2. Mortify the waveguide so the first 4 modes will propagate, and graph data
3. Fill the first waveguide with various material and graph its effect.

Process:

1. It is desired to design a rectangular waveguide that propagates only the lowest order mode TE10 and operates at 10 GHz. If the waveguide is air filled, determine the waveguide dimensions (a and b) such that the desired operating frequency is 38% above the cutoff frequency of the TE10 mode. Although the dimension b of waveguide is often taken as b=a/2, for attenuation considerations and also to improve the waveguide power handling capacity, it is desired to design a wave guide with the largest possible value of b. Furthermore, to avoid mode degeneracy, b should be chosen such that, b<a, but b>a/2. Determine the dimensions and simulate the waveguide using HFSS. Your dimensions must satisfy the requirements above. (There is not just one correct answer...)

   The dimension set was 24.2x 15 x 60mm, 0.2mm thick, copper shell. Calculation is based on the following:
   Waveguide propagates at TE_{10} at 10 GHz.
   Desired operating frequency is 38% above the cutoff frequency.

$$f_{cutoff} = 10 - 10 * 0.38 = 6.2GHz$$

   For a's width

$$f_{cutoff} = 6.2\ GHz = \frac{1}{2\sqrt{\mu\varepsilon}}\sqrt{\left(\frac{1}{a}\right)^2 + \left(\frac{0}{b}\right)^2}$$

$$6.2\ GHz = \frac{3 * 10^8}{2}\sqrt{\left(\frac{1}{a}\right)^2}$$

$$6.2\ GHz = \frac{1.5 * 10^8}{a}$$

$$a = \frac{1.5 * 10^8}{6.2 * 10^9}$$

$$a = 0.0242m = 24.2mm$$

For b’s length
Set maximum frequency cutoff to 10.01GHz.

$$f_{cutoff} = 10.01 \text{ GHz} = \frac{1}{2\sqrt{\mu\varepsilon}}\sqrt{\left(\frac{1}{b}\right)^2}$$

$$10.01\ GHz = \frac{3*10^8}{2}\sqrt{\left(\frac{1}{b}\right)^2}$$

$$10.01\ GHz = \frac{1.5*10^8}{b}$$

$$b = \frac{1.5*10^8}{1*10^{10}}$$

$$a = 0.015\ m = 15\ mm$$

2. Now, you want to make sure that the first 4 modes propagate. So, change the dimensions from part 1 above to make sure these modes all propagate.

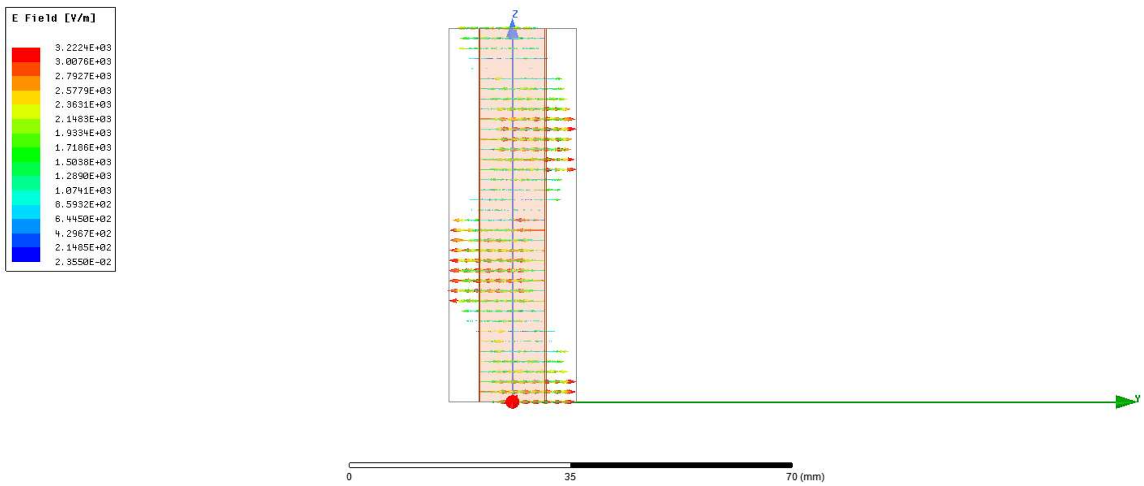
   Dimensions set to 24.2x20.57x60mm

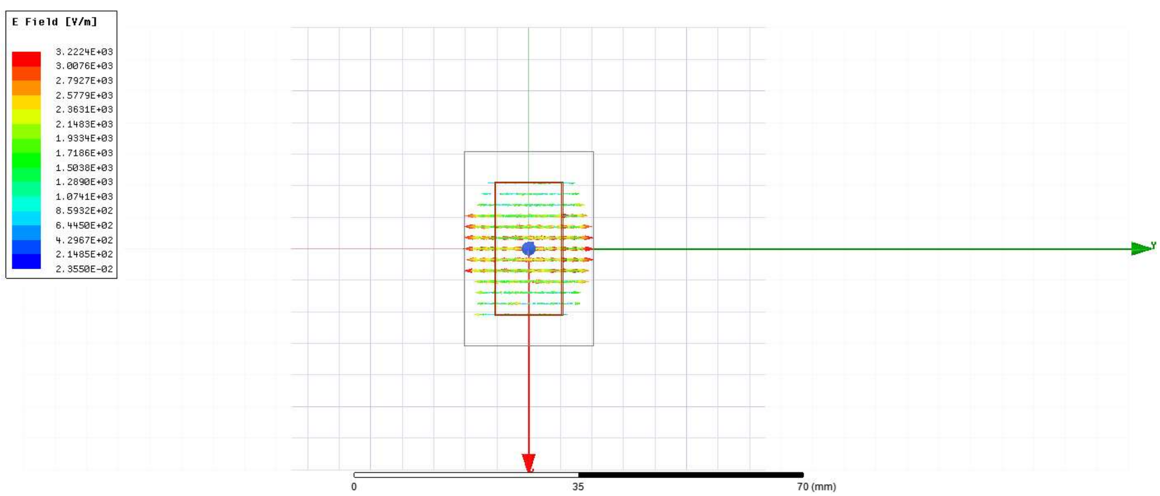
a. Determine the first 4 modes;
   The first 4 modes used in this simulation are TE10, TE01, TE11, TM11. TE20 does not seem to exist in this simulation.

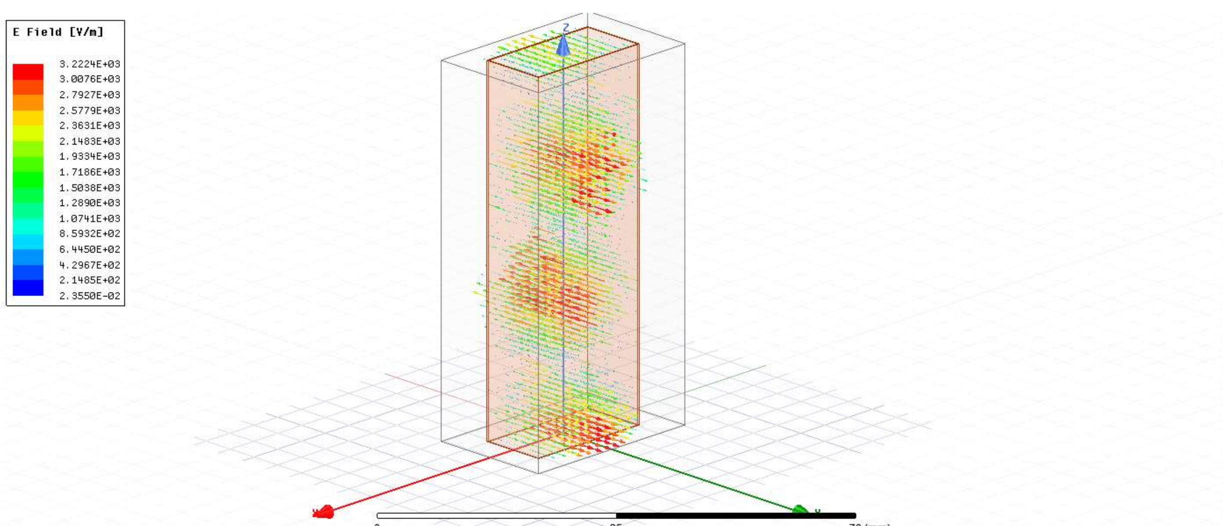
b. Plot the E and H Vector lines for the modes, on separate plots. Make sure to show top and side views.

c. TE10:

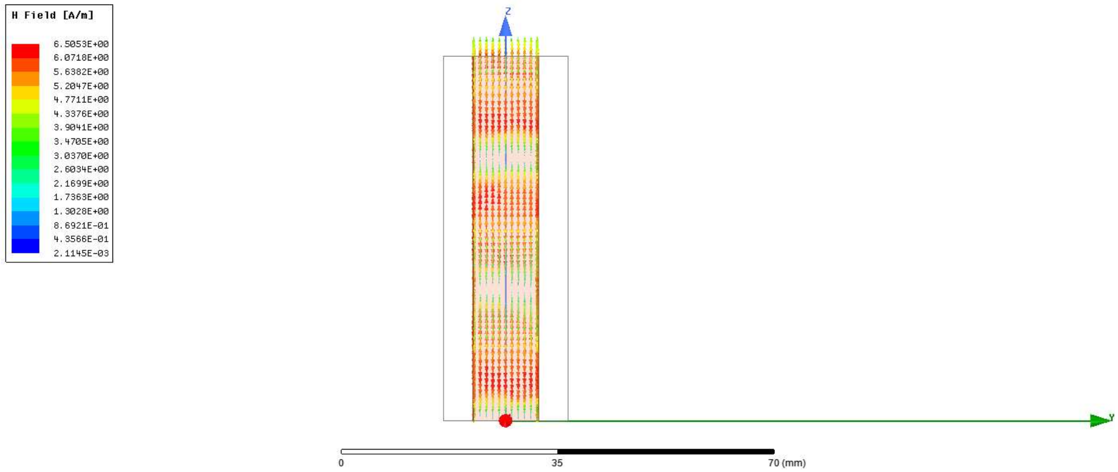
E Vector:







H Vector: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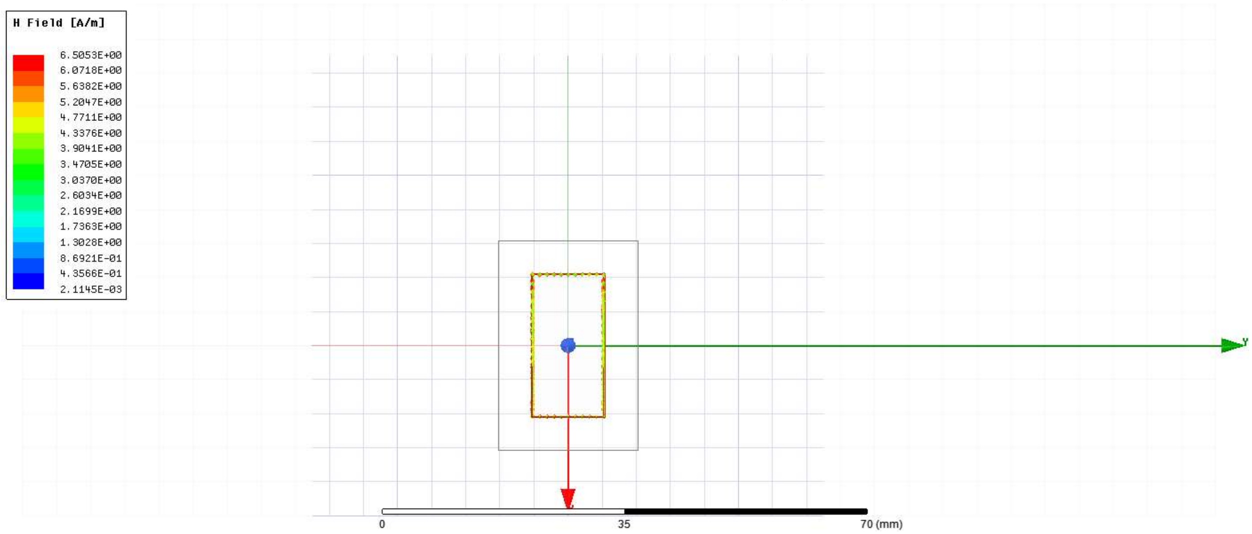
6.5053E+00
6.0718E+00
5.6382E+00
5.2047E+00
4.7711E+00
4.3376E+00
3.9041E+00
3.4705E+00
3.0370E+00
2.6034E+00
2.1699E+00
1.7363E+00
1.3028E+00
8.6921E-01
4.3566E-01
2.1145E-03
z
y
0
35
70 (mm)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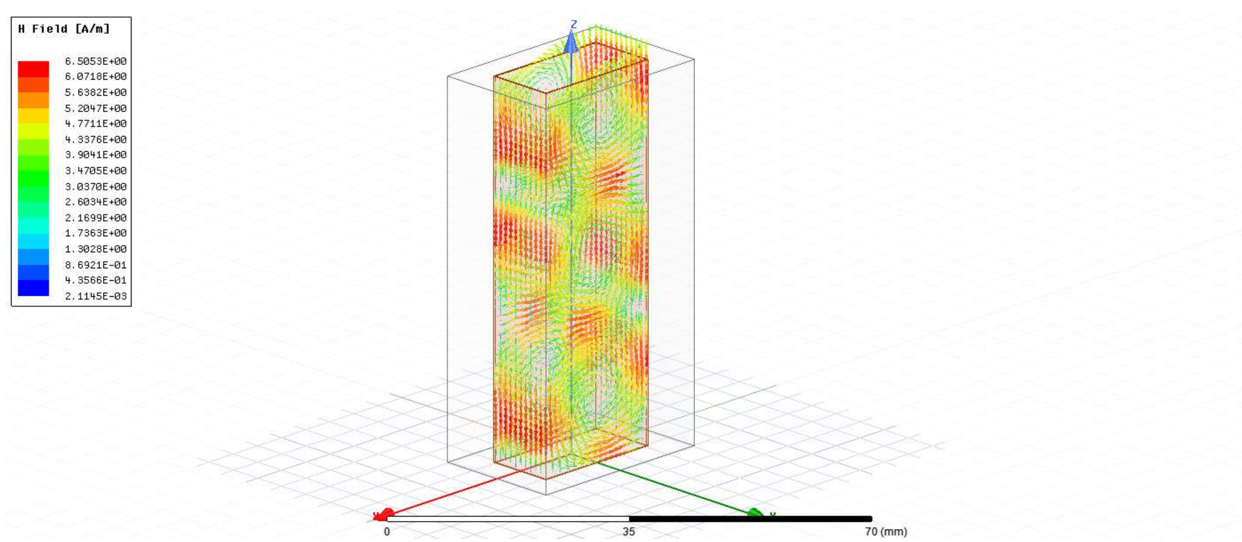
6.0718E+00
5.6382E+00
5.2047E+00
4.7711E+00
4.3376E+00
3.9041E+00
3.4705E+00
3.0370E+00
2.6034E+00
2.1699E+00
1.7363E+00
1.3028E+00
8.6921E-01
4.3566E-01
2.1145E-03
y
0
35
70 (mm)


H Field [A/m]
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6.0718E+00
5.6382E+00
5.2047E+00
4.7711E+00
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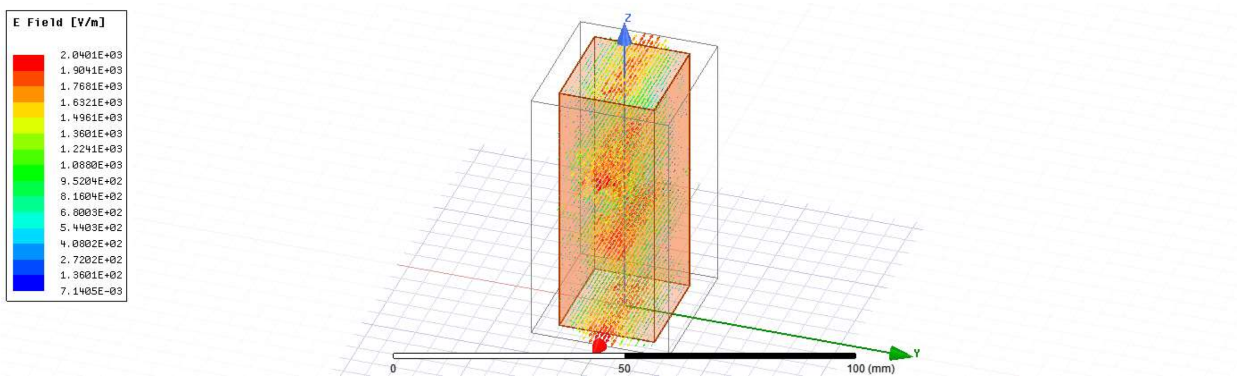
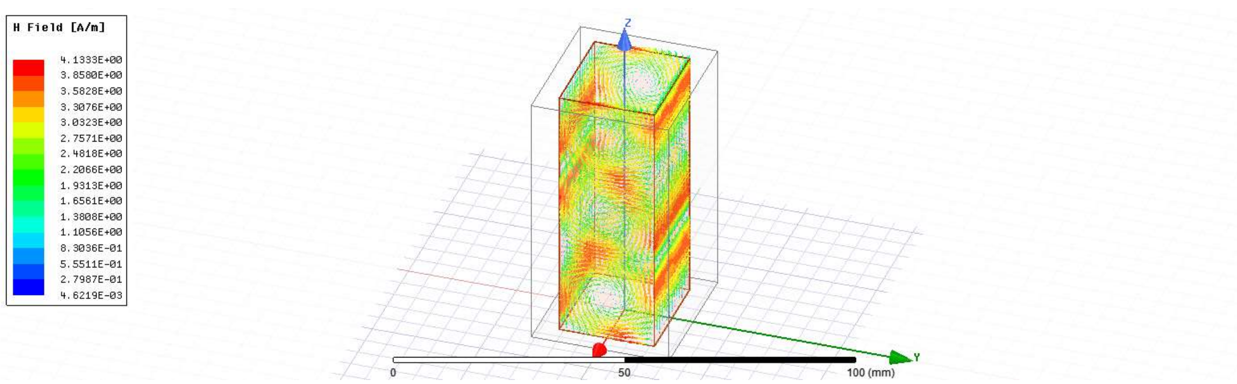
3.9041E+00
3.4705E+00
3.0370E+00
2.6034E+00
2.1699E+00
1.7363E+00
1.3028E+00
8.6921E-01
4.3566E-01
2.1145E-03
z
y
0
35
70 (mm)

TE01

E Vector:

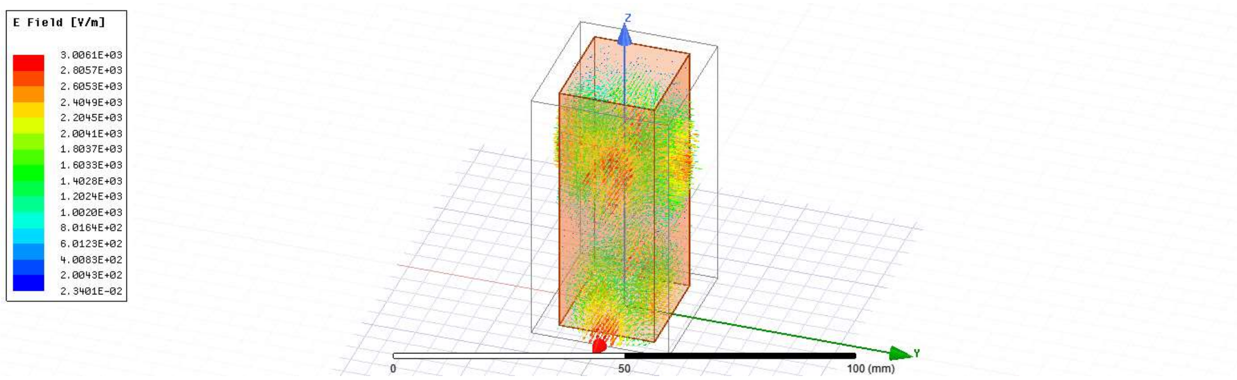


H Vector:

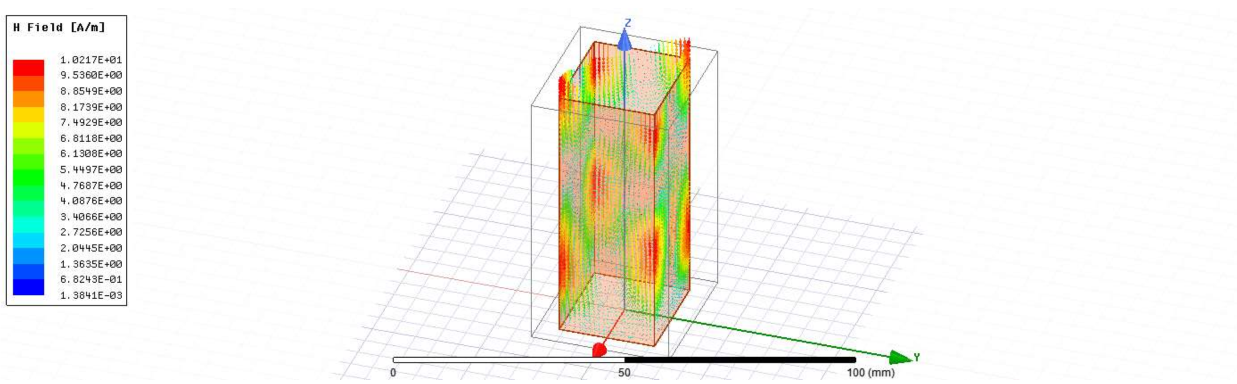


TE11

E Vector:

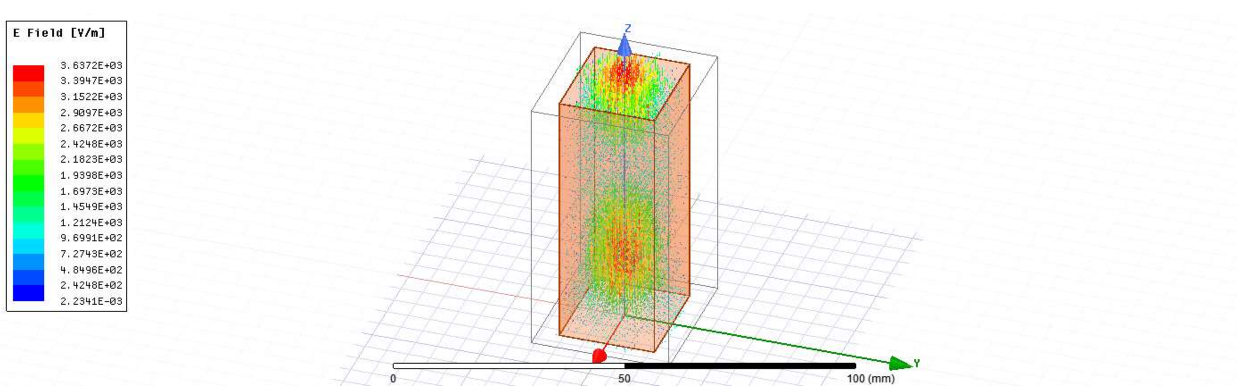


H Vector:

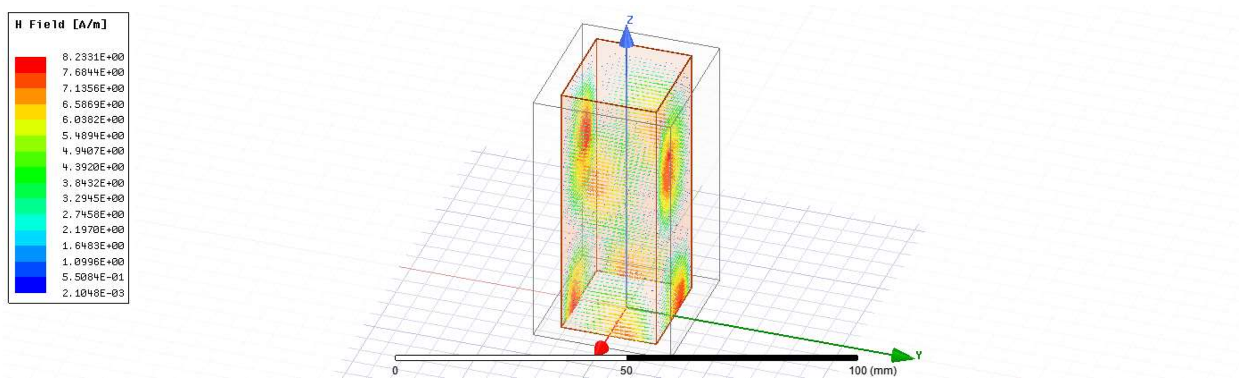


TM11

E Vector:



H Vector:



i. Show lines for all views

ii. Show surface or contour plots for all views

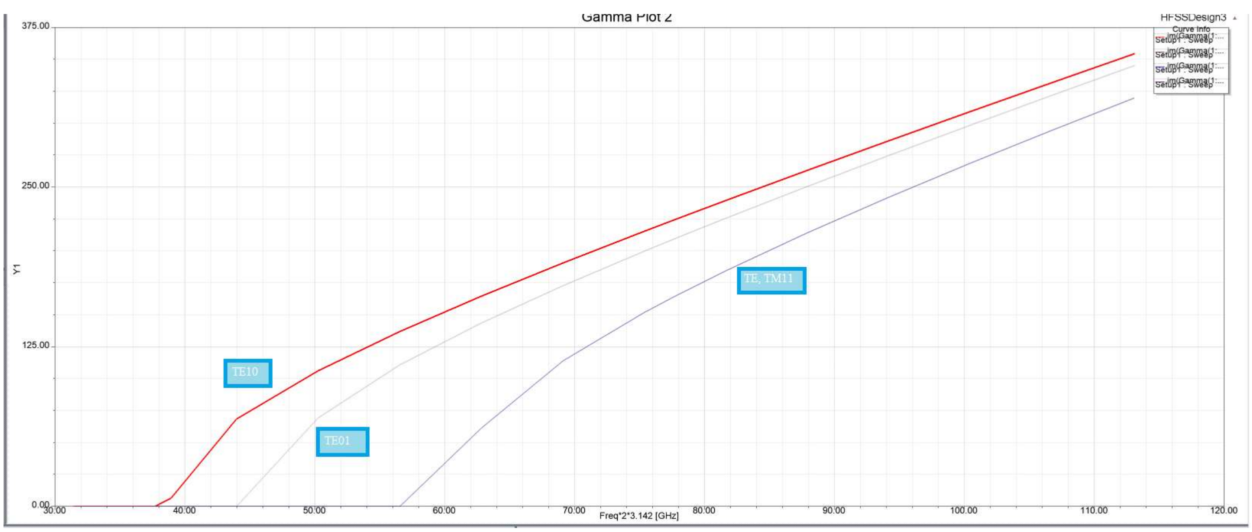
iii. Discuss the differences in TE10 and TM11 modes.

TE10 is propagating parallel to the wave guide, while TM11 propagates perpendicular to the waveguide.

The waveform of TM11 stretched out vertically

3. Using MATLAB, XCEL, or HFSS, plot ω vs. β curves for TE and TM modes for the

first four modes.



a. Analyze the propagation constant for the first four modes

b. Label the TEM case on this plot.

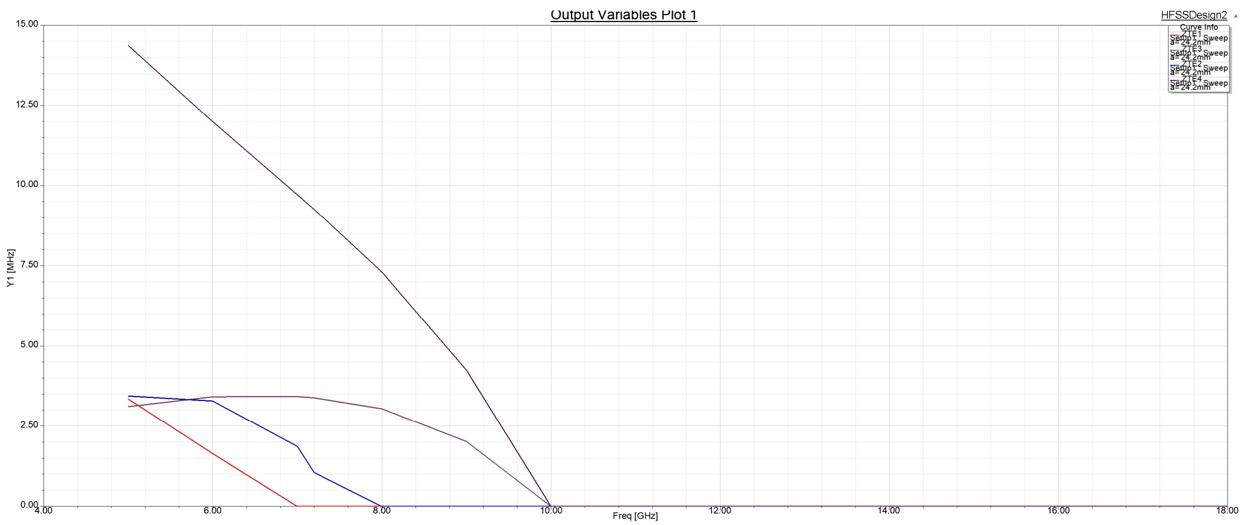
c. Show how you might find the phase velocity using this plot.

k = ω/β

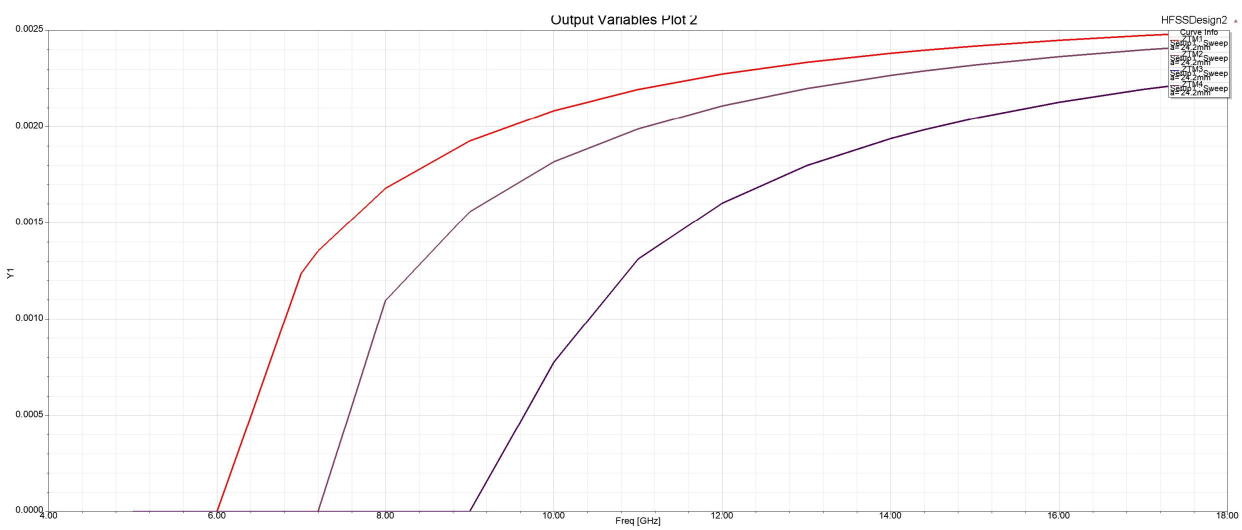
using the angular frequency and the im(gamma) value, the phase velocity can be found.

4. Using MATLAB or HFSS, Plot ZTE and ZTM vs. normalized frequency (f/fc). Is there an asymptote? If so, what is it?

ZTE



ZTM



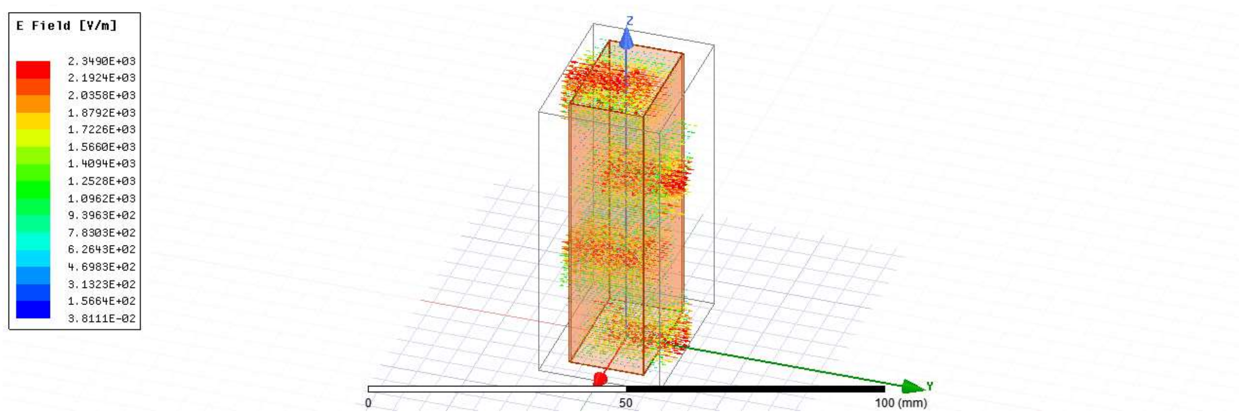
5. Now, take the waveguide in part 1 and fill with the following (you can choose

your own material properties for each case):

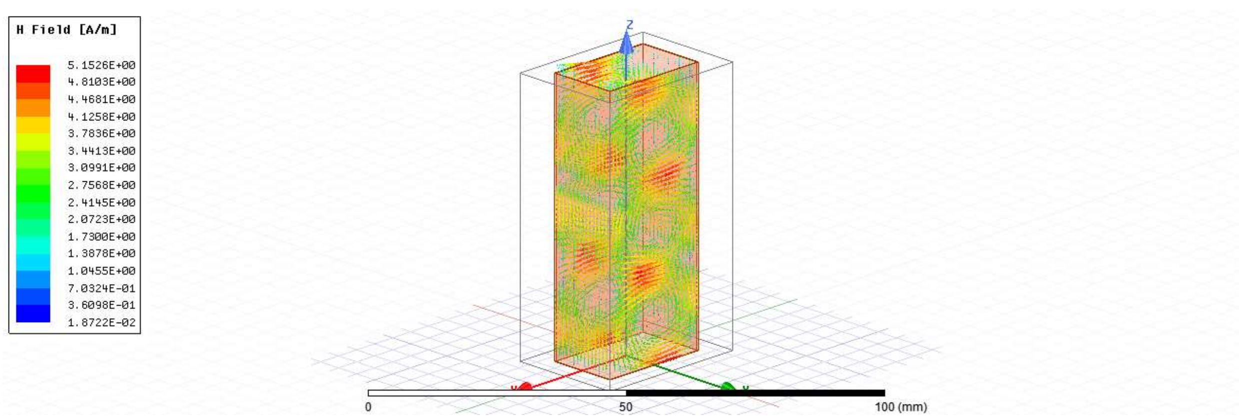
a. Lossless dielectric

The material filled the waveguide as a lossless dielectric is vacuum ($\mu_r = 1$, $\varepsilon_r = 1$), as it is the only true lossless dielectric material in existence. Like the original copper shell, the Electric field was not compressed or affected in anyway compare to the other samples.

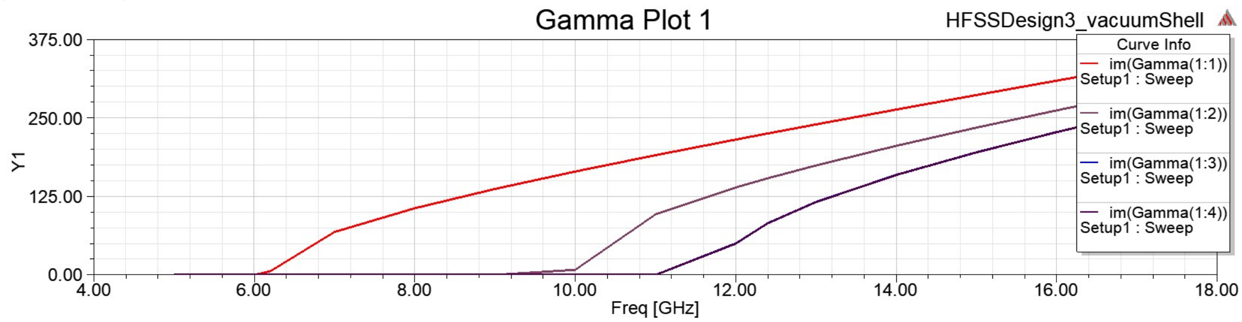
E Vector:



H Vector:



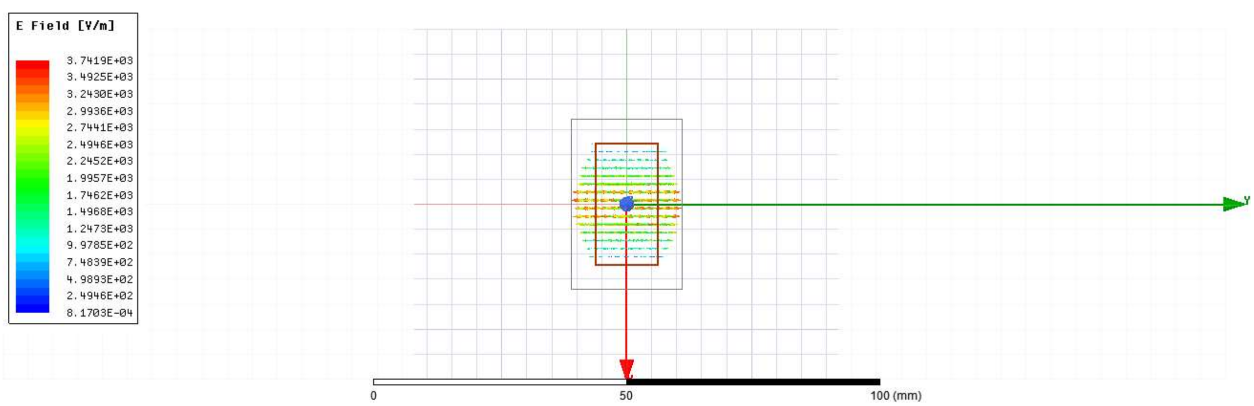
plot ω vs. β curves

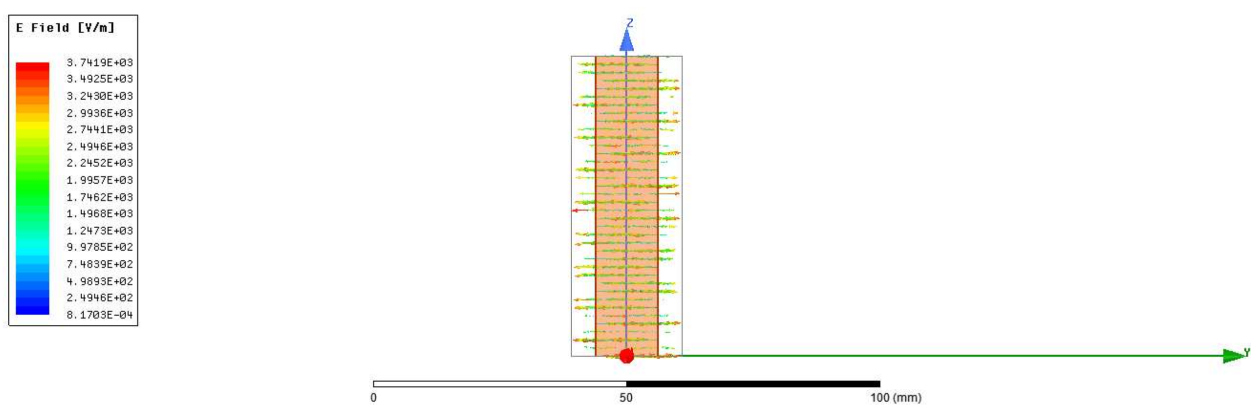


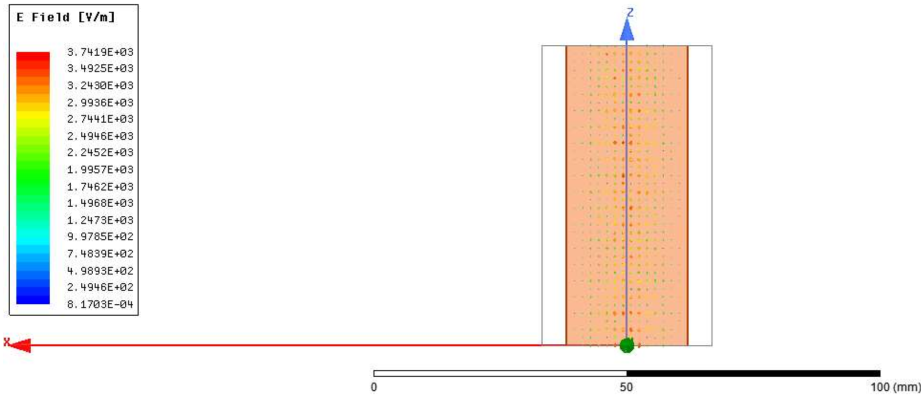
b. Magnetodielectric

The material used for waveguide made with a Magnetodielectric is a custom material ($\mu_r = 2$, $\varepsilon_r = 10$). The first choice was ferrite, however, due to technical reasons, the custom material was used as a replacement. The wavelength electric field is significantly compressed significantly and relatively to the other two samples. The magnetic field was induced just like normal. The B vs ω graph has become more linear, compare to the other samples.

E Vector:



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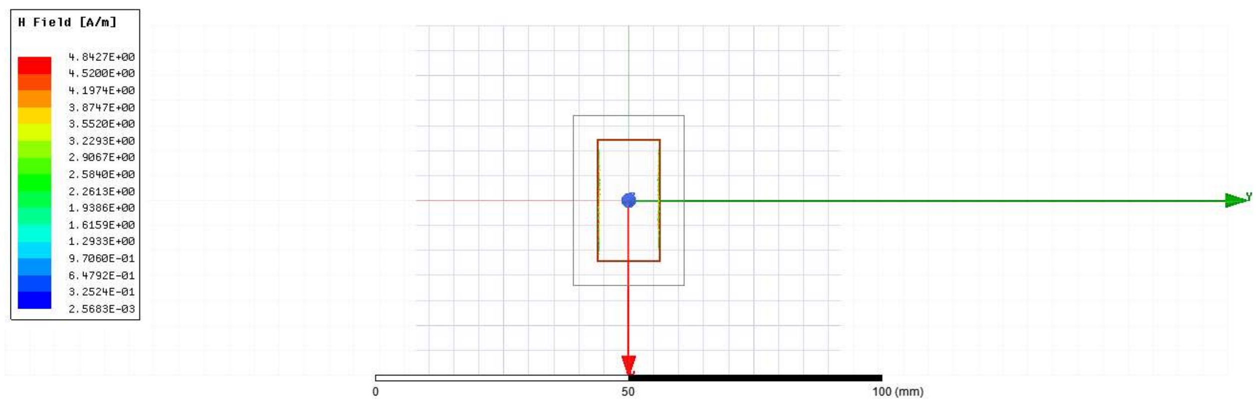
3.4925E+03
3.2430E+03
2.9936E+03
2.7441E+03
2.4946E+03
2.2452E+03
1.9957E+03
1.7462E+03
1.4968E+03
1.2473E+03
9.9785E+02
7.4839E+02
4.9893E+02
2.4946E+02
8.1703E-04
Z
X
0
50
100 (mm)

H Vector:


H Field [A/m]
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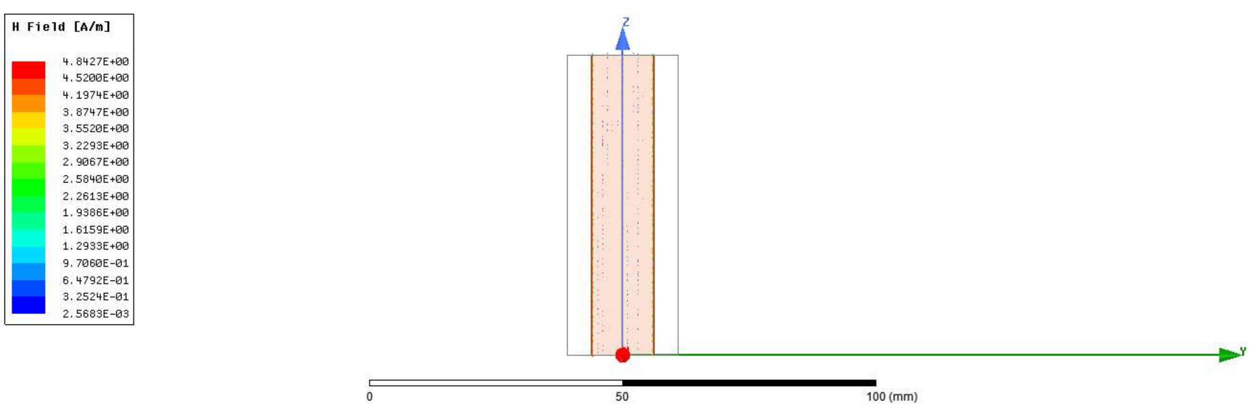
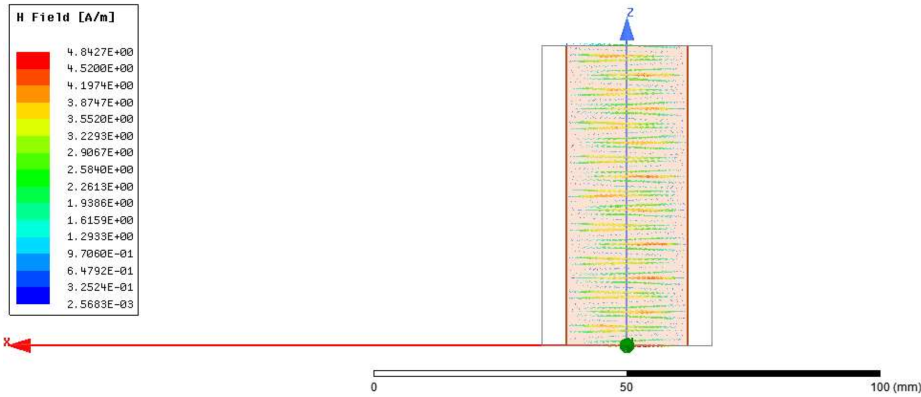
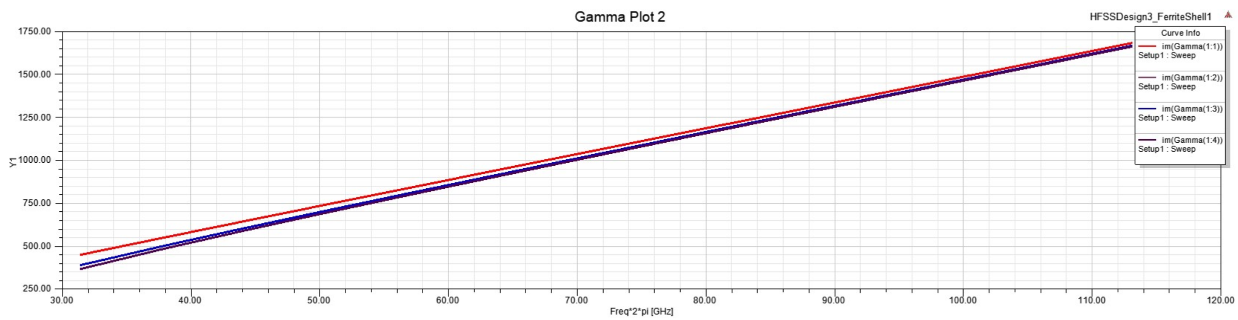
4.5200E+00
4.1974E+00
3.8747E+00
3.5520E+00
3.2293E+00
2.9067E+00
2.5840E+00
2.2613E+00
1.9386E+00
1.6159E+00
1.2933E+00
9.7060E-01
6.4792E-01
3.2524E-01
2.5683E-03
Y
0
50
100 (mm)


H Field [A/m]
4.8427E+00
4.5200E+00
4.1974E+00
3.8747E+00
3.5520E+00
3.2293E+00
2.9067E+00
2.5840E+00
2.2613E+00
1.9386E+00
1.6159E+00
1.2933E+00
9.7060E-01
6.4792E-01
3.2524E-01
2.5683E-03
Z
Y
0
50
100 (mm)

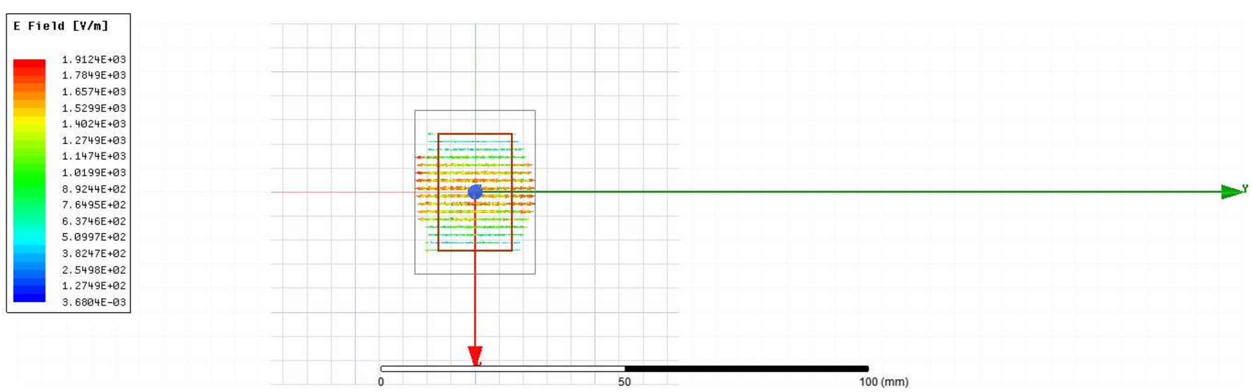


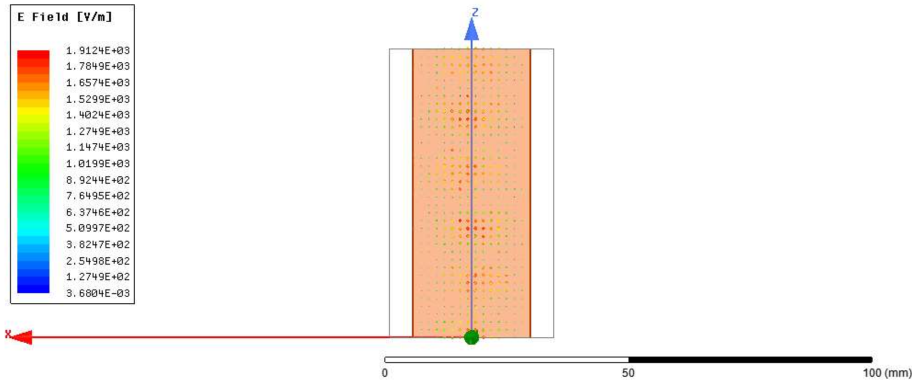


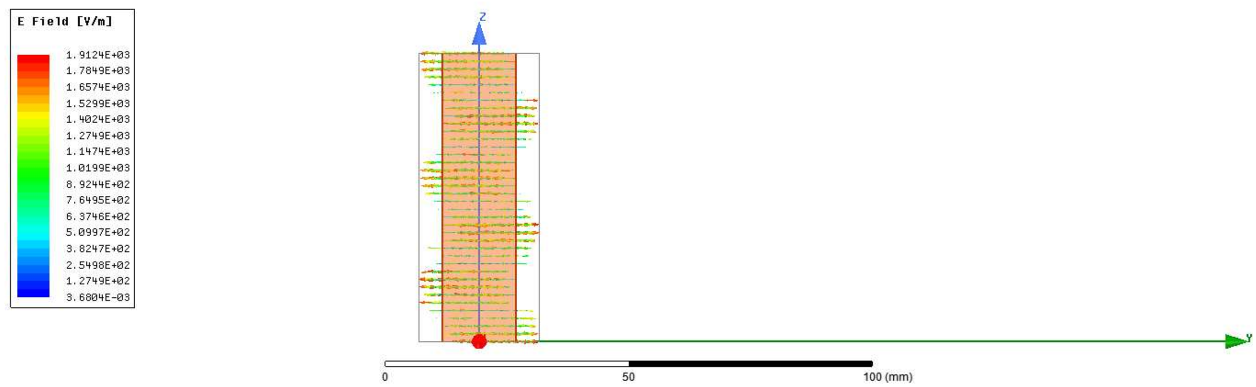
c. Lossy dielectric

The material used for waveguide made with a Lossy dielectric is Teflon (μ_r = 2.1, ε_r = 1). Both the electric and magnetic field was are distorted by the material. It was however not as compressed as the magnetodielectric.

E Vector:




E Field [V/m]
1.9124E+03
1.7849E+03
1.6574E+03
1.5299E+03
1.4024E+03
1.2749E+03
1.1474E+03
1.0199E+03
8.9244E+02
7.6495E+02
6.3746E+02
5.0997E+02
3.8247E+02
2.5498E+02
1.2749E+02
3.6804E-03
z
x
0
50
100 (mm)


E Field [V/m]
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1.7849E+03
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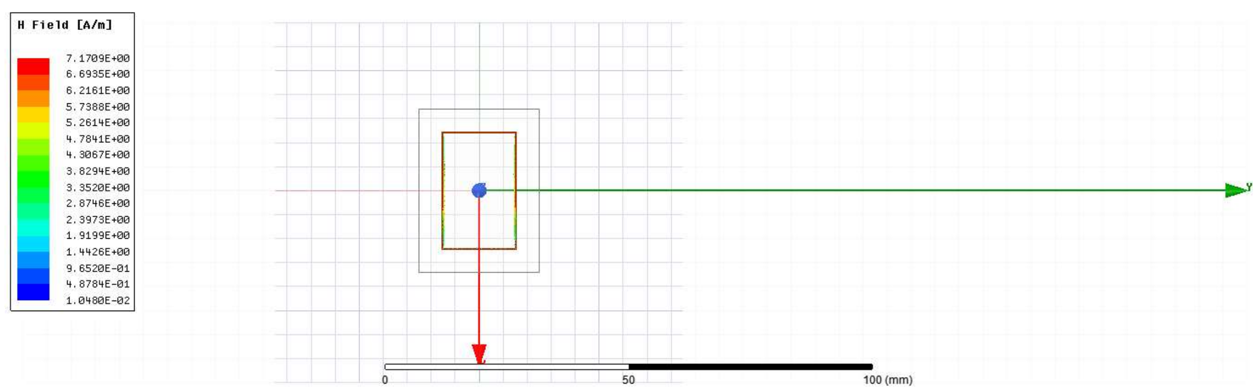
1.5299E+03
1.4024E+03
1.2749E+03
1.1474E+03
1.0199E+03
8.9244E+02
7.6495E+02
6.3746E+02
5.0997E+02
3.8247E+02
2.5498E+02
1.2749E+02
3.6804E-03
z
y
0
50
100 (mm)

H Vector:


H Field [A/m]
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4.3067E+00
3.8294E+00
3.3520E+00
2.8746E+00
2.3973E+00
1.9199E+00
1.4426E+00
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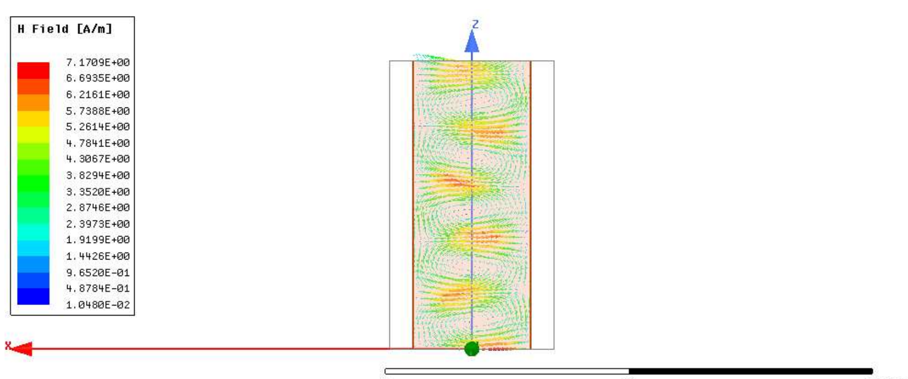
1.0480E-02
y
0
50
100 (mm)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6.6935E+00
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4.3067E+00
3.8294E+00
3.3520E+00
2.8746E+00
2.3973E+00
1.9199E+00
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9.6520E-01
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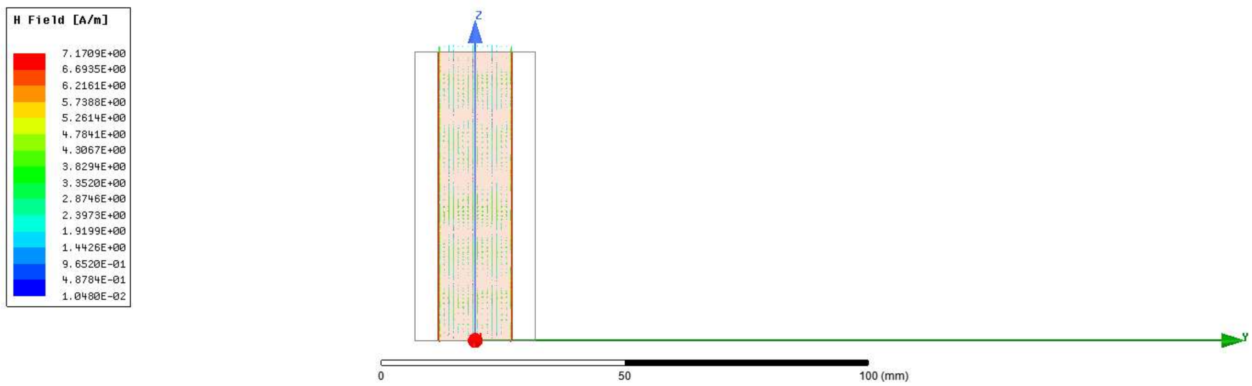
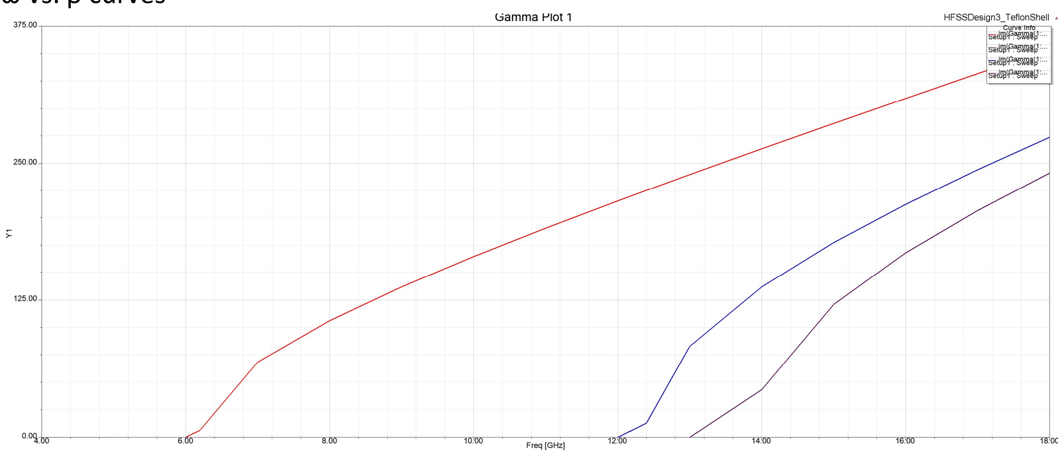
1.0480E-02
z
x
0
50
100 (mm)



ω vs. β curves



• For each case, state clearly the material properties that you used (you can pick a particular material and look up the properties and use those or come up with your own material parameters) and plot TE10 and TM11 modes and compare with your results in part 2.

• Also, repeat part 3 for a.-c.