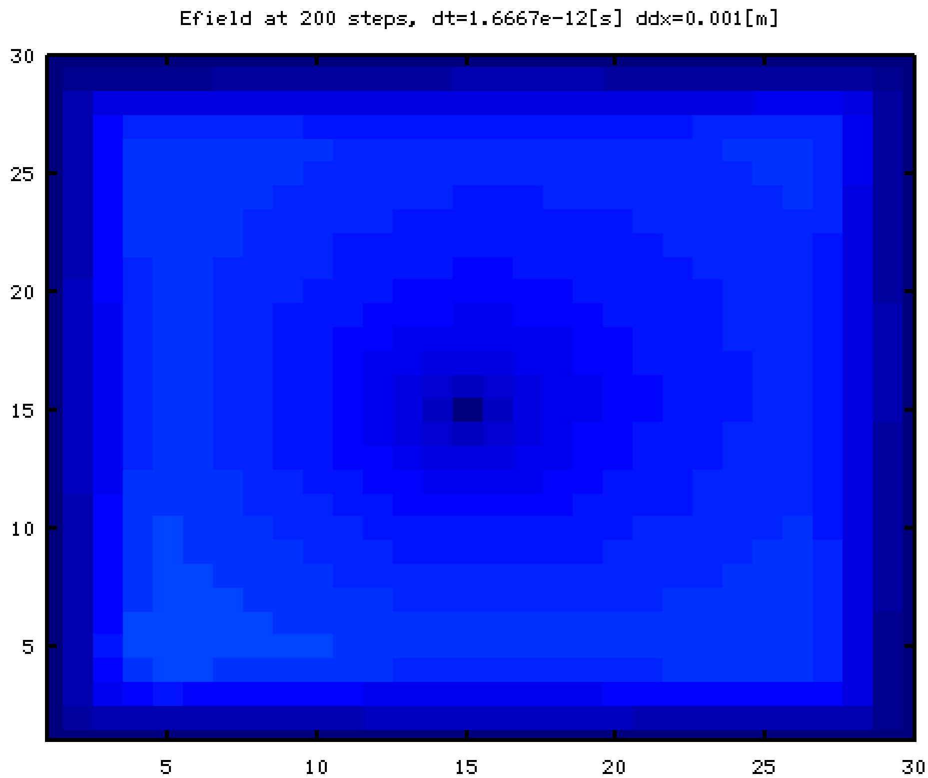
ECE5340/6340: Homework 10
Answer Key

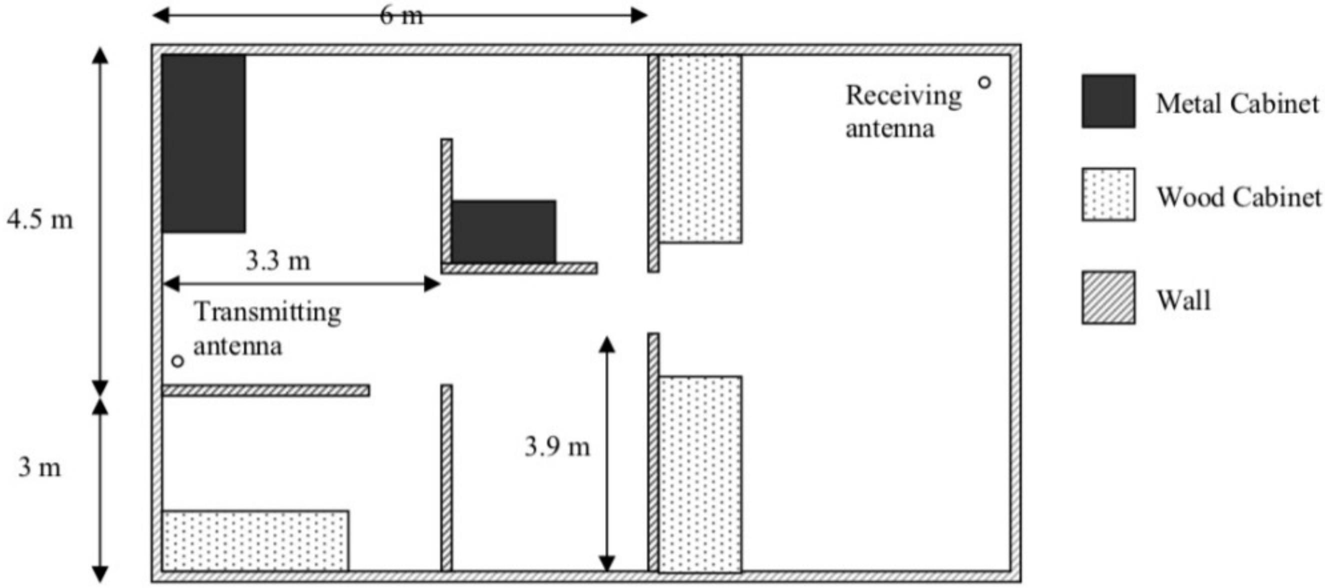
Problem 1

(10 points) Obtain from the WEB the 2D TM PML code. Make sure that the code is working properly, with the excitation pulse being well absorbed by the boundary conditions. Turn in a plot of the E field at 200 iterations. In the plot title include the values for dt and dz with units.



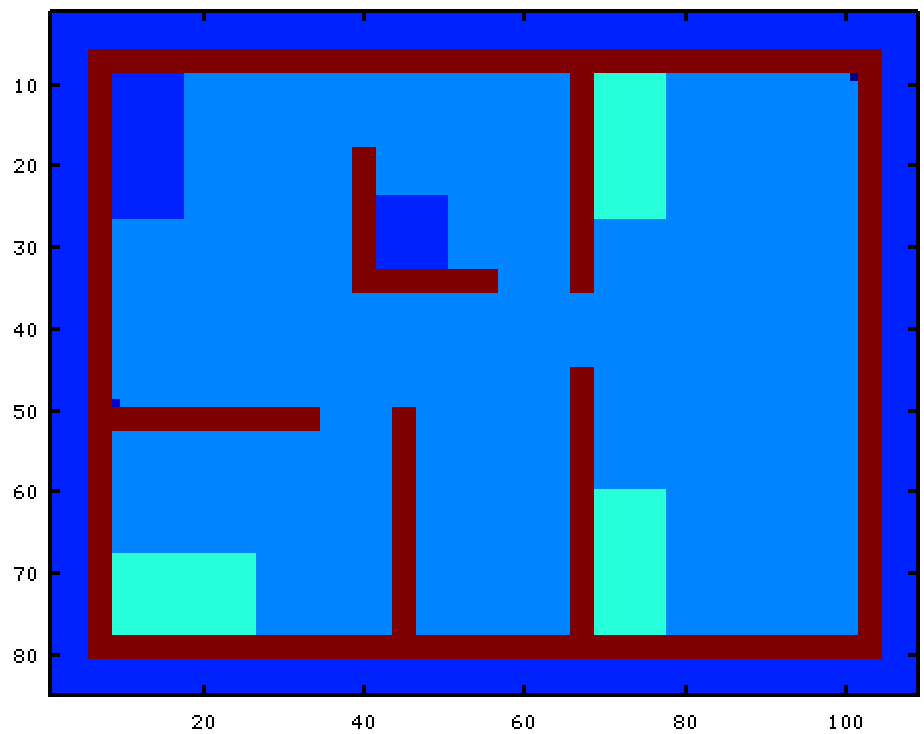
Problem 2

Consider the following approximation of the floor plan an office space with low frequency LAN antennas (100 MHz):

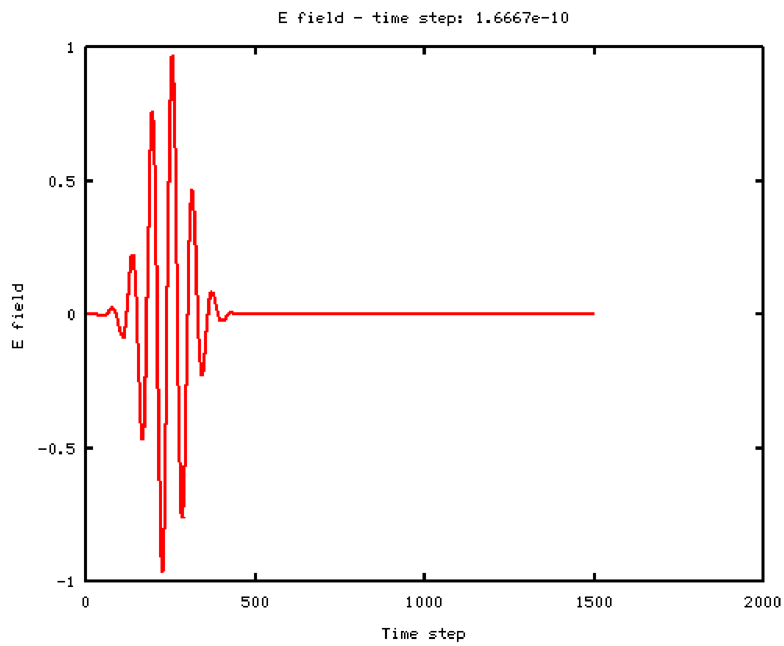


Wall thickness is 30 cm, the office space is 9.9 x 7.5 m, and some of the other dimensions are indicated in the figure. All the cabinets are 0.9 x 1.8 m, with only a smaller one of dimensions 0.9 x 0.9 m near the center of the room. Doors are 0.9 m wide. Consider the metal as perfect conductors, wood characterized by epsilon_r = 3 and σ = 0.001 S/m, and the wall by epsilon_r = 10 and σ = 0.02 S/m. Input the floor plan in a FDTD grid suitable for operation at a frequency of at least 100 MHz. Position your feed (Transmitting antenna) as in the figure. Note that the choice of the low frequency is motivated by the desire to reduce the size of the computational space; In reality, frequencies around 2.4 GHz should be used for these kind of applications. However, the approach at this higher frequency would be the same.

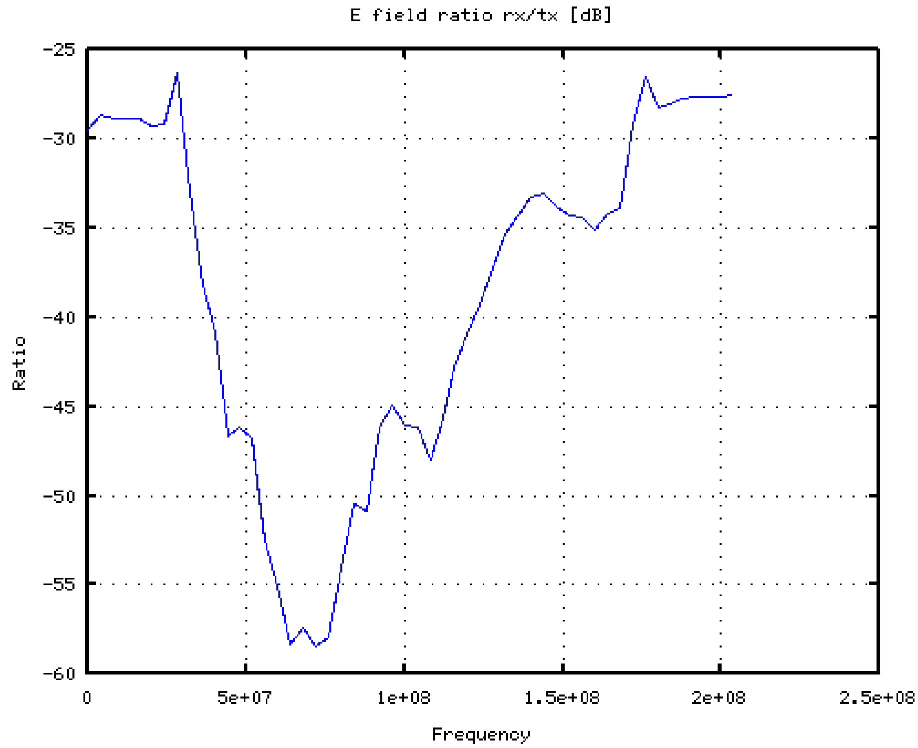
1. **(20 points) Plot the building floor plan.**



2. **(30 points) Launch a pulse containing frequencies of at least 200MHz. Perform the DFT of the input pulse and of the signal you receive at the location of the receiving antenna in the figure at the following frequencies: 50 MHz, 75 MHz, and 100 MHz. What is the ratio between received and input signals for each frequency?**



Signal at source, Gaussian Pulse with fc = 100MHz, BW=100MHz



Attenuation at receiver using Gaussian Pulse, at time-step=1500

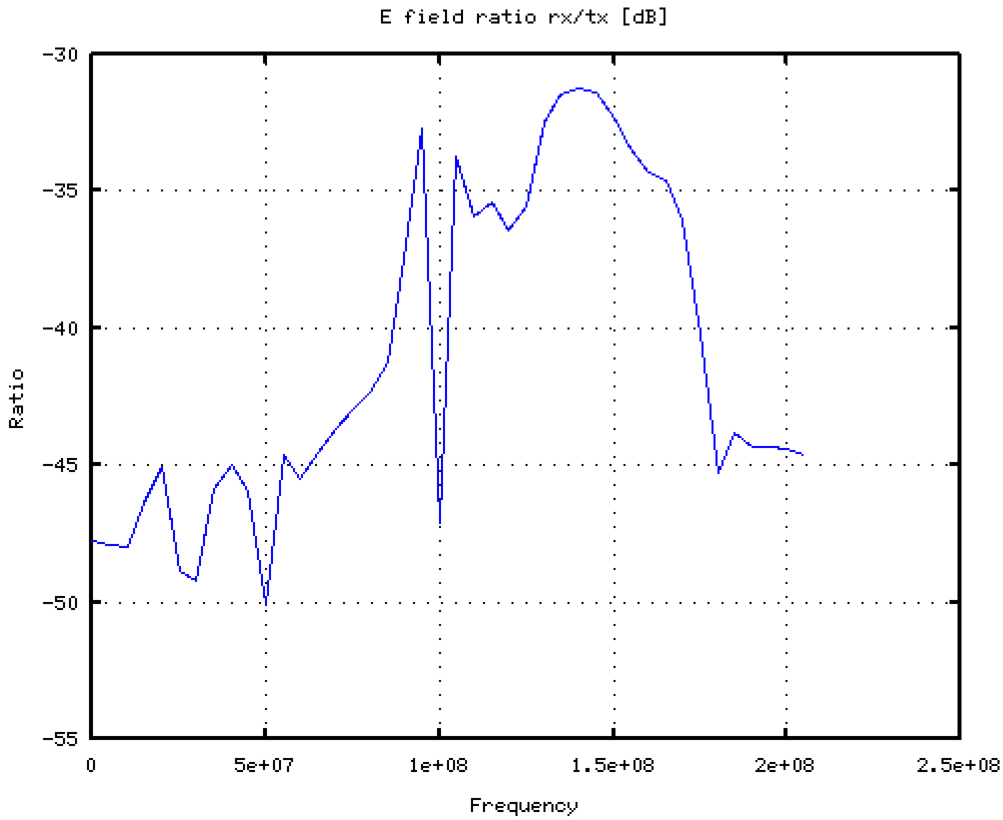
Using the Gaussian pulse excitation, we get an attenuation of about:

-46 dB at 100 MHz
-57 dB at 75 MHz
-47 dB at 50 MHz

Note that these values will change with your interpretation of the layout, the position of your source, the pulse used, and the time-step of your simulation when the DFT was calculated.

3. (20 points) Repeat the problem but using a sinusoid at 100 MHz this time. Do you get the same results for each frequency as before? Why?

The same result happens only for the 100 MHz component. For the sinusoid, the frequencies present are strong 100 MHz component and small components introduced by the easing in ramp and by the numerical errors. Since outside 100 MHz the ratio represents two small numbers, comparable to noise, the only value that can be trusted is the 100 MHz component.



Results using 100 MHz sinusoid excitation

4. (20 points) Study how do your results change by altering the conductivity and dielectric constant of the walls and the wood cabinets. Would you recommend using more wooden cabinets or more metal cabinets? Why?

Changing the wall material to be more conductive (sigma=1 [s m], epsilon=10), and once more using a Gaussian pulse, it can be noticed that the electric field is contained within the boundary of the walls this time, which results in more energy transmitted to the recording point.

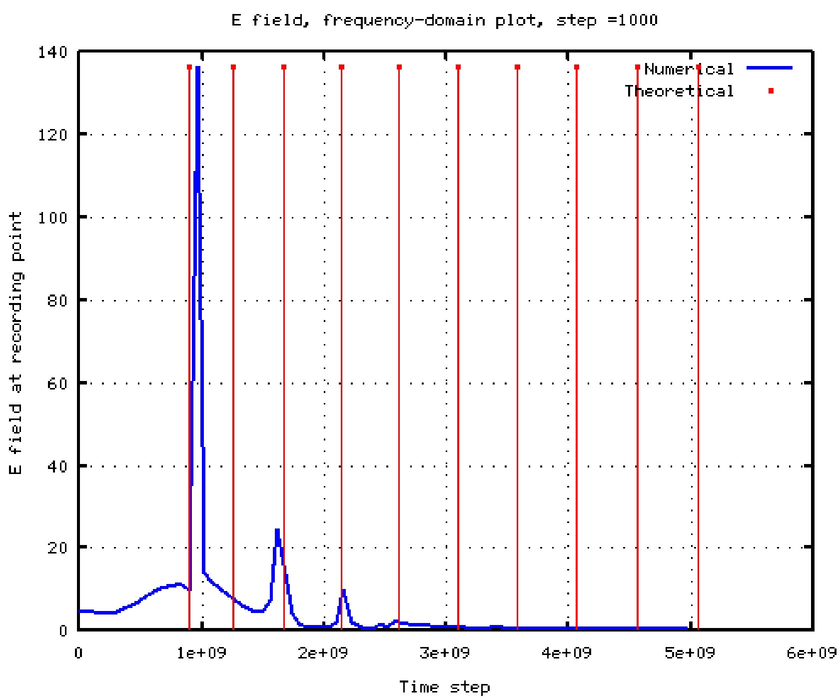
The E field at the recording point is larger in comparison with the previous case.

Problem 3 (Optional, Extra Credit)

Consider a rectangular waveguide, with its cross-section modeled in a 2D FDTD TM mesh. You can choose the dimensions of your waveguide and try your code for different dimensions. Place an excitation pulse in a point in the cross-section of the waveguide and choose another point where to record the history of the electric field. Save the history of the electric field in an array, and take the DFT of this array using Matlab's fft() function as shown in class.

1. By plotting the magnitude of the DFT vector, can you find the TM-mode cutoff frequencies of the waveguide? Why? Explain, and include a plot of the DFT.

The pulse is reflected by the metallic waveguide. After some time, the non-resonant frequencies taper off due to destructive interference, while the resonant frequencies, which are paired to the propagating modes, subsist.

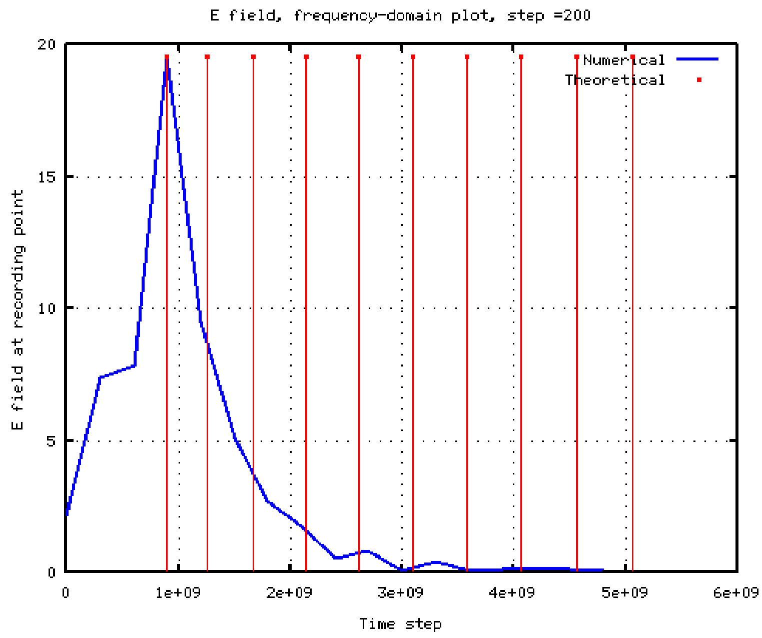


2. Compare the TM-mode cutoff frequency value you obtained on the first part with the theoretical value.

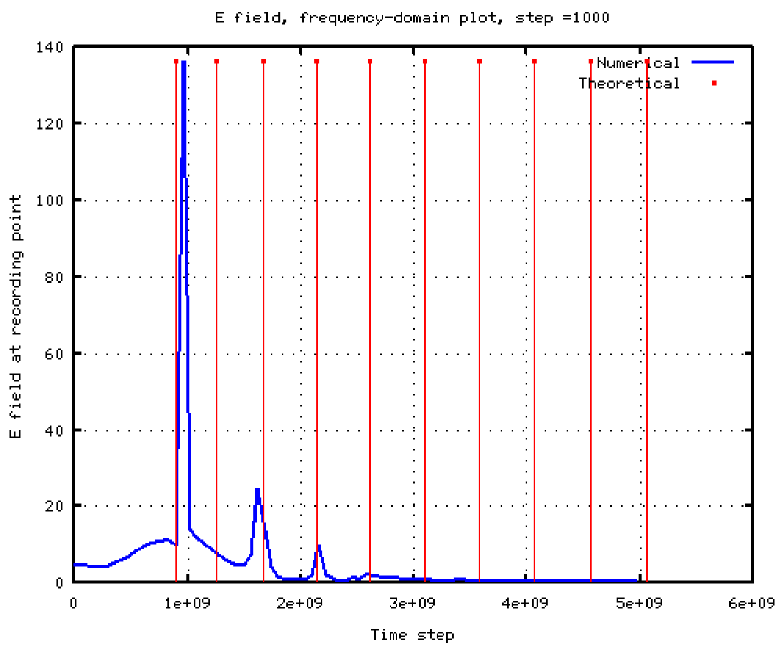
Refer to the plot in part 1, both numerical and theoretical values have been included in it.

3. Comment on the changes you see by altering the resolution of the grid and the length of time of the simulation.

The DFT resolution is better the longer the simulation runs and there are more time-domain data points to transform. For an example, compare the plots below, corresponding to 200 and 1000 time steps.



Plot at 200 time steps



Plot at 1000 time steps