Electromagnetics Class Project (2 Credits)   Spring 2017

You will work on the class project of the Electromagnetics course, which accounts for 2 credits, during this summer semester. You are to team up with one other student in the class for all the technical portion of the project. You can simply adopt the grouping of your previous experiments. One team turn in one project report and both team members get the same grade for this class project. **The report is due July 20.** This class project pertains to the study, design, simulation and fabrication of microstrip antennas and frequency selective surface as well as operating a microwave radar system. Fundamentals of patch antennas, frequency selective surface and microwave radar can be found in the book chapter and slides provided to you. You may also need to dig out some useful information from other books or online resources by yourself. There are in total two problem sets for you to choose. Each problem set has four topics and detailed descriptions are as follows. Topic 1 is mandatory while Topic 2 to 4 can be replaced by some customized topics. You can propose any topics related to electromagnetics that you would like to explore and need to get my permission by **June 25**. Your proposals must have sufficient details of procedures and expected results.

CST software will be used to simulate the antennas. Your TAs will provide necessary help on this. The software is installed on computers in the lab 1A103, which will be open for you during the summer semester.

Successful completion of the topics includes the simulation work, measurements and reports. TAs will check your simulation results as well.

<u>Problem Set 1</u>

Topic 1

Read 14.1 and 14.2.1 to gain basic knowledge of patch antenna.

Design two patch antennas working at the **same frequency** but **different substrates** given below.

Each team performs the design of the two antennas at a unique frequency ranging from **2 to 5 GHz with a step of 0.2 GHz**, meaning in total 18 different frequencies for 16 teams. I will randomly assign the frequency of each team.

Substrate 1 has a relative permittivity of **4.6**, is lossless and has a height of 1 mm.

Substrate 2 has a relative permittivity of **10.2**, is lossless and has a height of 1 mm.

The copper layer on top and bottom of the substrate is 35 μm.

Use the probe feed method for both antennas. The characteristic impedance of the air-filled coaxial probe is 50 Ω. Its inner conductor has a diameter of 2 mm and outer conductor has a diameter of 4.6 mm. You will need to figure out the location of the coaxial probe where the optimal matching condition at your design frequency can be achieved.

Use CST software to draw the models of the two antennas in two different files. Set all the materials and simulation parameters. After the simulations are done, you need to check the simulation results to judge if some design considerations are fulfilled, which includes the following aspects.

1) Check $|S_{11}|$ (return loss) to see if the antenna is working at your design frequency. This can be judged by observing if the dip of the $|S_{11}|$ curve is at your design frequency. If not, adjust the size of the patch or the location of the feed as well.
2) Check $|S_{11}|$ to see if acceptable matching condition is obtained. Acceptable matching condition means that $|S_{11}| < -10$ dB at the working frequency. If not, try to tune the location of the coaxial probe. Tuning the location of the coaxial probe may in turn alter the working frequency of the antenna, so you need to readjust the size of the patch.
3) Try to make the relative bandwidth (frequency range in which $|S_{11}|$ is less than -10 dB) as wide as possible, which is defined as $(f_{\text{high}} - f_{\text{low}})/f_{\text{design}}$. Here f_{high} and f_{low} denote the higher and lower frequency of the band, respectively. For at least one antenna, try to make its relative bandwidth greater than 2%.
4) Also check the radiation pattern, efficiency and gain. The reason to try two different substrates is to give you a chance to see how the relative permittivity of the substrate affects the design parameters. Some comparison between the two sets of design parameters and results should be given in your report.

Topic 2

Read 14.8 to gain basic concepts of patch antenna array.

Design two patch antenna arrays working at the **same frequency** as you used in Topic 1. Use the one you designed with relative permittivity of **4.6** as the element of these arrays. Each array has **four elements**.

For the first array, use the microstrip line feed method. Also use a coaxial probe port at the beginning of the microstrip line. The characteristic impedance of the microstrip line and air-filled coaxial probe are both 50 Ω. Use three T-junction power dividers to obtain equal amplitude and phase of the excitation signals for the four elements. You can also use some other types of power dividers to achieve the same effect. The four elements of this array should be arranged in a line.

For the second array, use the probe feed method. CST has a function that can assign arbitrary amplitude and phase to each array element. Try at least 6 different combinations to see the overall effects and enclose the results in your report. The four elements of this array should be arranged in a square manner (2 × 2).

Use CST software to draw the models of the two arrays in two different files. Set all the materials and simulation parameters. After the simulations are done, you need to check the simulation results including the working frequency, return loss, matching, radiation pattern and gain.

Topic 3

Read the slides regarding radar to gain basic concepts of a radar system.

Use the radar system to test some **moving** objects like metal balls, metal model aircraft, human, unmanned aerial vehicle, and various automobile. You can also test multiple objects at the same time. Record their moving trajectories and reflected signal levels. Try to see if the system can distinguish between different objects, for example a car and a bus.

Topic 4

Use the anechoic chamber to measure fabricated antenna in ***Topic 1*** with a relative permittivity of 4.6 and the first type antenna array in ***Topic 2***. Compare their measured patterns with the simulated ones.

For students choosing the **Problem Set 1**, please give me your detailed design parameters and layout for the antennas to be fabricated (mentioned in ***Topic 4***) by **July 4**.

<u>Problem Set 2</u>

Topic 1

Same as the ***Topic 1*** of the ***<u>Problem Set 1</u>***.

Topic 2

Same as the ***Topic 3*** of the ***<u>Problem Set 1</u>***.

Topic 3

Read the slides regarding frequency selective surface (FSS) to gain basic concepts.

Design a transmission type metal FSS that can only allow the transmission of waves at 24 GHz (the working frequency of the radar system) but suppress other frequencies. This means $|S_{11}|$ curve has a very sharp dip at 24 GHz.

The FSS should be made on a copper layer with a thickness of 35 μm. Use the substrate with a relative permittivity of **4.6** and a height of 1 mm to support the metal layer. Actually, the substrate is not necessary, but it is convenient to fabricate the FSS on a circuit board.

Topic 4

Use the anechoic chamber to measure fabricated antenna in ***Topic 1*** with a relative permittivity of 4.6. Compare the measured pattern with the simulated one.

Put the fabricated FSS in ***Topic 3*** just in front of the radar antenna to see if good performance of the radar system can still be obtained. Test some moving objects to verify this.

For students choosing the **Problem Set 2**, please give me your detailed design parameters and layout for the antenna and FSS to be fabricated (mentioned in ***Topic 4***) by **July 4**.