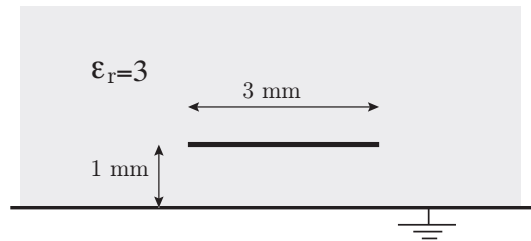# Microwave theory 2015: Computer session

1. Parallel plate transmission line

Use at least two different mesh sizes when you do your calculations so that you can see that the solution has converged.

a) Find the line parameters L and C, and the characteristic impedance Z_0 for a parallel plate above a ground plane as given by the figure. The thickness of the plate is 0.1 mm. Follow the steps given on page 45 in the book. Notice that the medium around the microstrip is a dielectric material with $\epsilon = 3$. The capacitance can be calculated by two methods and you should try both of them. You will find that there is a difference between the two methods. This indicates that for a structure with corners the finite element method gives good, but not extremely good results. Compare your results with the approximate expressions given on page 44. You will find that the approximate expression is not accurate for this structure.

- Method 1: $C = Q/V$ where Q is the charge per unit length ρ_ℓ of the plate. You have two options to calculate ρ_ℓ; by integrating the surface charge density over borders of the the plate, or by integrating it over the borders of the large rectangle. One gives a result that is closer to what you get in method 2. Why?

- Method 2: $C = 2W_E/V^2$ where W_E is the electric energy per unit length. The electrostatic energy is a predefined quantity that you find under **Results→Derived results→Global evaluation**. Integrate over the area between the two rectangles.

b) Decrease the distance between the plates from 1 mm to 0.1 mm and calculate the capacitance again. Compare with the expressions on page 44. Is the agreement better?
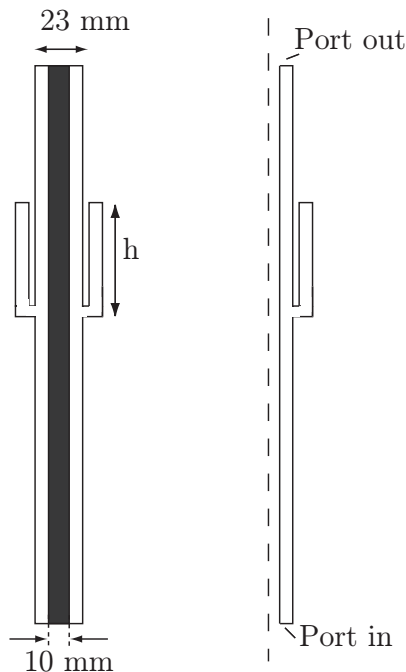
2. S21 and S11 for a notch filter

Figure 1: The notch filter. The structure is axially symmetric and the figure shows the cross section.

Build a coaxial cable with a notch filter (bandstop filter) with a stop frequency at 3 GHz. The dimensions are as in the figure. Find the height h such that the frequency 3 GHz is stopped. Let Comsol plot the S21 parameter in dB scale. Also plot the S11 parameter in dB scale.

Do the following steps:

1. Start Comsol and pick **2d-axisymmetric → Radio Frequency → Electromagnetic waves → Frequency domain**.

2. Draw the geometry. The dashed line is the axis of symmetry. You only draw the right half of the cross section. This is the part consists of the three rectangles in the right part of the figure. Let the total length be 25 cm and place the notch filter at the middle of the coaxial cable. When you have drawn the three rectangles you can use **Geometry → Boolean operations → union** to form the union of the three rectangles.

3. Choose air as material.

4. The default boundary condition on all lines is perfectly conducting. You should replace the lines at the inlet and outlet with ports. This is done by **electromagnetic waves → Port**. Use **Type of port → Coaxial**. Make sure that you have added the selection. The lower port should be the input port (Wave excitation on) and the upper one the output port (Wave excitation off).

5. Choose the frequency range and frequency step by **Study 1 → Step 1 Frequency domain** Click on range to the right of **Hz** and choose 1 GHz as start frequency, 5 GHz as stop frequency and 0.1 GHz as step. Once you have the bandstop frequency at the right place you may narrow the frequency range and step size.

6. You may refine the mesh if you like.

7. Compute (right click on Study)

8. You can now look at the norm of the electric field for different frequencies (or some other quantity).

9. In order to get the curves for the S parameter you click **Results → 1 D Plot Group** and the **1 D Plot Group → Line graph** Let data set be **from parent**. In selection you use **Manual** and add the lines for the two ports. As y-axis data you choose **S21 dB** and for x-axis data **frequency**. Plot by clicking on **Plot** on top of the frame.

10. Change the dimension of the filter until you get a stop at 3 GHz. Remember to activate all rectangles and the union after you have made a change.