Microwave theory 2017: Computer session

1. Coaxial cable

A coaxial cable has an inner conductor with radius $a = 1$ mm and an outer conductor with inner radius b. The region between the conductors are filled with a lossless plastic material with $\varepsilon_r = 4$ and $\mu_r = 1$. The radius b is chosen such that the characteristic impedance is 50 Ω.

a) Use the formulas on page 45 in the book to determine b. Also calculate the capacitance C with format long in Matlab.

b) Find the capacitance C from Comsol. Use the scheme described on page 47 in the book. Compare your result with the analytic expression. How many digits do you get?

c) Find the bandwidth of the cable. The bandwidth is defined as the width of the frequency band where only the TEM mode can propagate in the cable. To find out the frequency of the second mode you may start from scratch again. Do the following steps:

   – Choose 2D and choose Electromagnetic waves frequency domain under Radio Frequency. Then press study, click on choose eigenfrequency and done.
   – Draw the coaxial cable and fill it with the material, as in b)
   – Right click on Electromagnetic waves and choose perfectly conducting boundary conditions for all surfaces (it is probably already chosen).
   – Choose extremely fine mesh.
   – Now it is time to find the frequencies where higher order modes will start to propagate. This is done by solving an eigenvalue problem. We will look at this next week but you can do it in Comsol without knowing the details. Click on Step 1:Eigenfrequency under Study. Choose 10 eigenfrequencies and give a starting value. You may pick 10 GHz (1e10) as a starting value.
   – Click Compute and find the bandwidth by finding the lowest eigenfrequency. Comsol often finds non-physical solutions (spourious solutions). These fake solutions reveal themselves by having very cluttered field maps. A real resonance has a very nice looking field map. Experiment with the different options Comsol has for plotting the fields. Look at field maps of different components for the electric and the magnetic field.

2.Wave propagation in rectangular waveguide

a) Use COMSOL to find the cut-off frequencies of the ten lowest modes in a rectangular waveguide with cross section $0 < x < 10$ cm and $0 < y < 4$ cm. Use the same method as in the previous example. Use different meshes and check the accuracy by comparing with the analytic expressions. You can tell if it is a TE or TM mode in COMSOL by plotting a certain field component. Which component should you plot?

b) Now you can take a look at the propagation of some TE_{m0} modes along the waveguide in COMSOL. Again go to **2D** and **Electromagnetic waves frequency domain** under **Radio Frequency**. As a study you choose **Frequency domain**. We look at the waveguide from above.

- Draw a 10 cm high and 1 meter wide rectangle.
- Fill it with air.
- Right click on **Electromagnetic waves** and choose **Port**. Mark the left side of the rectangle. Choose **Rectangular** under **Type of port**. Then let the power be on and choose **Transverse electric** as **Mode type** and 1 as **Mode number**. That will generate the fundamental mode at this port.
- Choose again **Port** and let that be the right side of the rectangle. Use the same as the other port with the exception that the power is off.
- Choose frequencies. Let starting frequency be 1 GHz and the end frequency 4 GHz with a step size of 0.2 GHz.
- Compute.
- Look at the $z-$component of the electric field to see the waves for some different frequencies.
- Make a movie by Right click on **Export**. Choose **Animation** and **Player**. Choose **Dynamic data extension** under **Sequence type**.
- Look at some different modes. Mode number 2 is TE_{20} and so on.

c) Make a rectangular waveguide that makes one or several turns and take a look at the wave propagation along that waveguide. You glue together regions by choosing **Booleans and Partitions** under **Geometry**. Then pick **Union**.

d) Create a new file and go to **3D** and look at the same waveguides there. Start with the straight one.