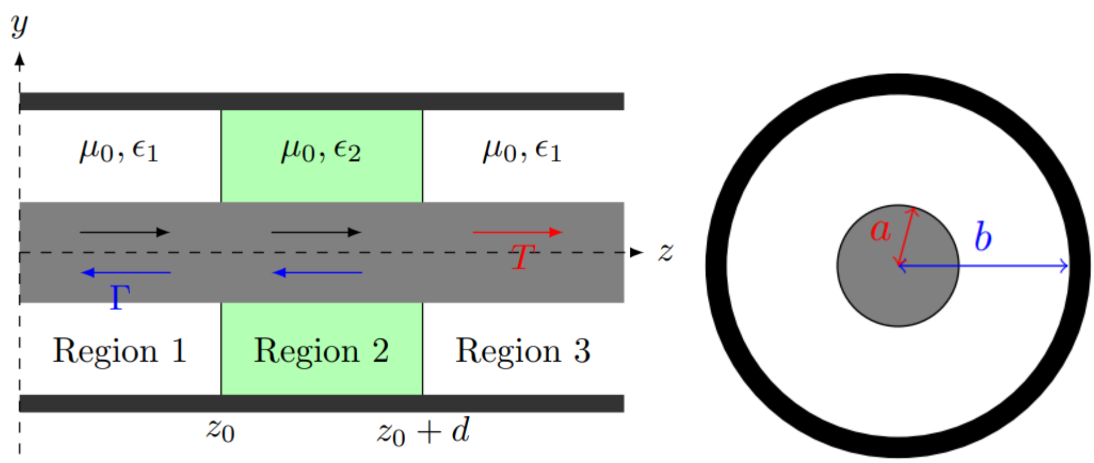
Electromagnetics Class Project (2 Credits)

Spring 2022

You are to team up with another student for all the technical tasks of this project. You can simply adopt the grouping of your previous lab sessions. One team only needs to turn in one project report and both team members get the same grade for this class project.

The report is due June 18, 23:59 pm (maybe changed according to university policy).

This project pertains to the measurement of complex permittivity using a coaxial waveguide. Schematic configuration of the problem is shown below. The inner and outer radii are respectively a and b. The two conductors can be considered as PEC. A nonmagnetic material, with a thickness of d (known) and unknown **complex permittivity ε_2**, is under test and resides in Region 2. Region 1 and Region 3 are filled with a nonmagnetic lossless material having permittivity ε_1. An incident wave propagating in $+z$ direction in Region 1 hits the material in Region 2. Then multiple reflections happen at the two interfaces at $z = z_0$ and $z = z_0 + d$. In reality, the material to be investigated is machined into a ring-shaped slab having the same inner and outer radius as the coaxial waveguide and a thickness of d in the z direction, which can guarantee that the material can exactly fit inside the waveguide (no air gap between the material and the metal walls of the waveguide). We can use a vector network analyzer (VNA) to measure the reflection coefficient Γ (S_{11}) and transmission coefficient T (S_{21}), both are complex numbers with amplitude and phase. The major task you need to do is **determining the complex permittivity ε_2 making use of Γ and T**.



You need to follow these general steps.

1. Write out the electric and magnetic fields (or voltages and currents) in all the three regions using the method similar to homework problem 8.9. Hint: using the voltages and currents, i.e.,

the transmission line method, may be simpler.

2. Use the boundary conditions to establish four equations.

3. Solve for Γ and *T*, which will be expressed in terms of ε_2. Hint: you may use the "solve" function in MATLAB.

4. Finally, use the provided Γ and *T* (explained in the following note) to derive ε_2 from the two equations of Γ and *T* you got in step 3. For the cases that may have multiple solutions of ε_2, you need to provide all the possible solutions.

5. Use your obtained ε_2 and other known parameters to build a model in CST and simulate the Γ and *T*. This step can verify if your obtained ε_2 is correct.

Note: each group needs to do this problem for **two different materials**. Each group will draw lots to obtain the following parameters:

1. Coaxial waveguide dimension *a* and *b*.
2. Thickness *d* of the material under test.
3. ε_1 in Region 1 and 3.
4. Frequency.
5. Γ and *T*.