Lab5 Simulation of Rectangular Waveguides by CST

Name ____________________ Student ID ___________________________

TA __________________ Score ___________________________

Objectives

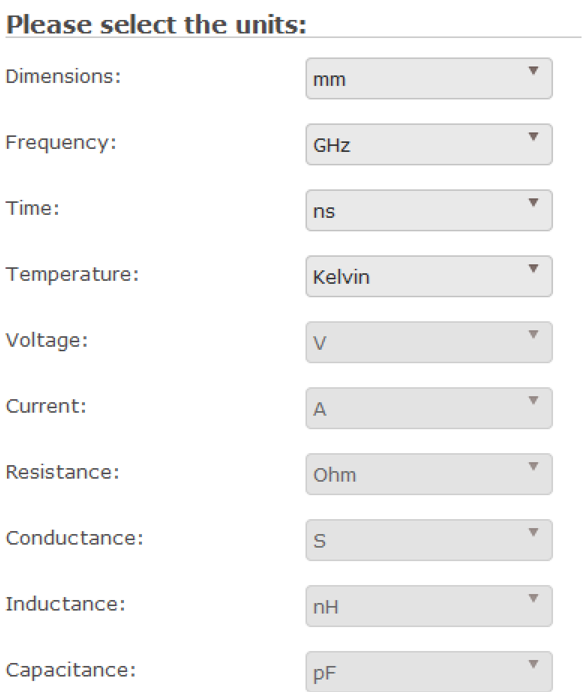
1. To learn to use 3D electromagnetic simulation software CST to build rectangular waveguide and carry out simulation.
2. To understand the properties of transmission line and waveguide

Understand and build rectangular waveguide simulation environment.

Rectangular waveguide is one of the earliest transmission lines used to transmit microwave signals, and it still has many applications today. A large number of components, such as couplers, detectors, isolators, attenuators and slot lines, are used in various standard waveguides from 1GHz to over 220GHz. Due to the trend of miniaturization and integration, a large number of microwave circuits now use planar transmission lines, such as microstrip lines and striplines, instead of waveguides. However, waveguide is still needed in many applications, such as high power system, millimeter wave system and some precision detection applications.

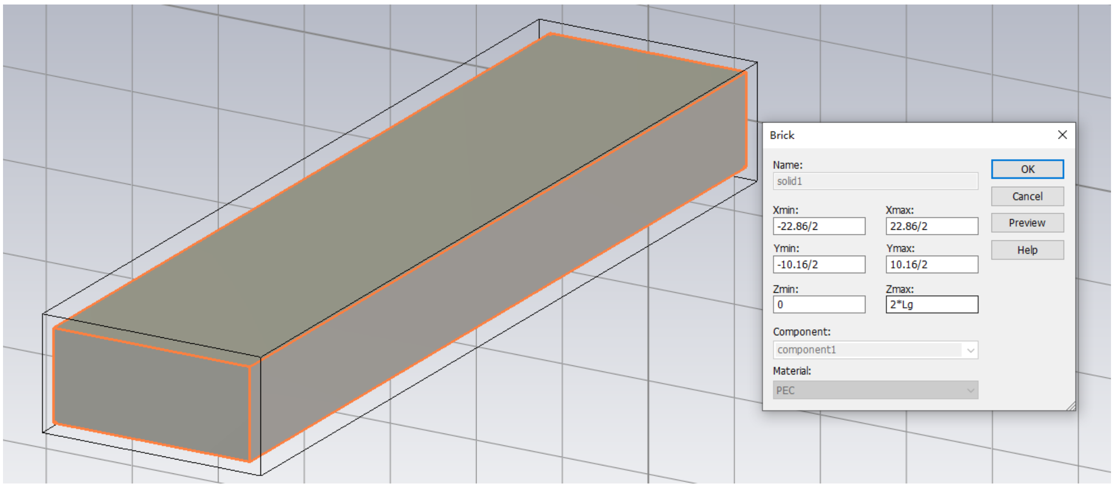
1. New project

Create New Project -> MW & RF & Optical -> Antennas -> Waveguide -> Time Domain -> Unit Set（Compared with the figure below, it does not need to be changed in general） -> Frequency -> Finish.

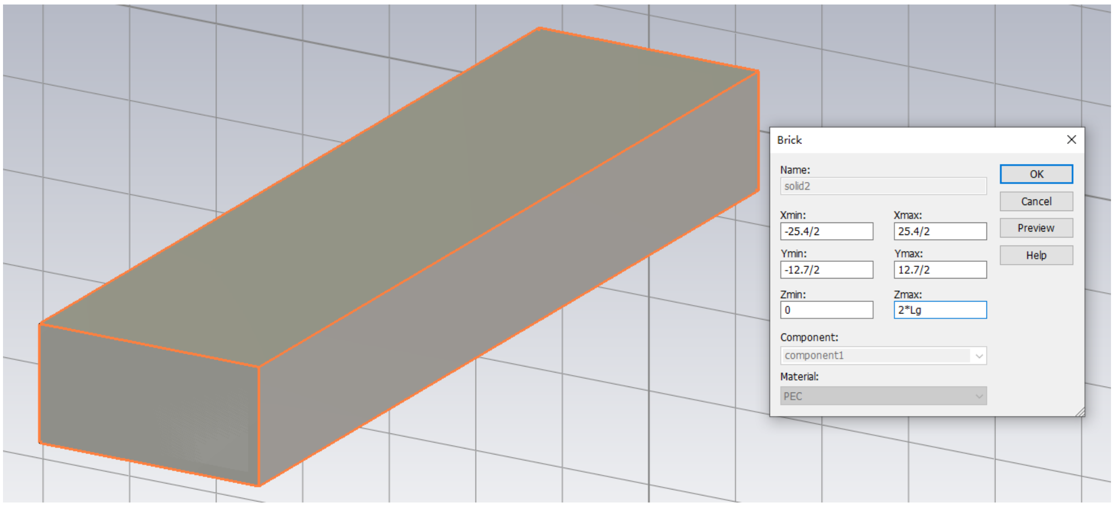


2. Draw a waveguide

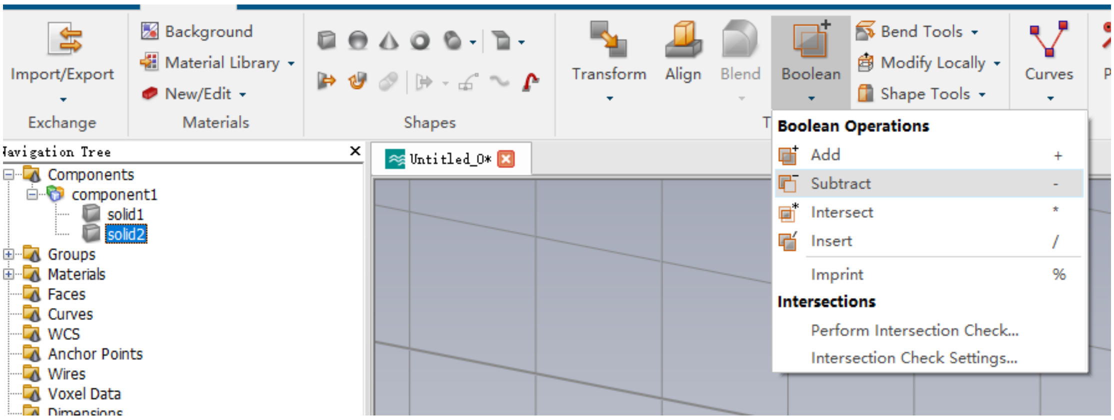
(1) We build a WR90 rectangular waveguide with a cross-section size of 22.86 * 10.16mm and a frequency range of 8.2Ghz ~ 12.4Ghz. The length of Z direction is 2 times the guided wavelength, which will be mentioned in the subsequent experimental requirements and needs to be calculated. Here, the parameter Lg is used for guided wavelength.



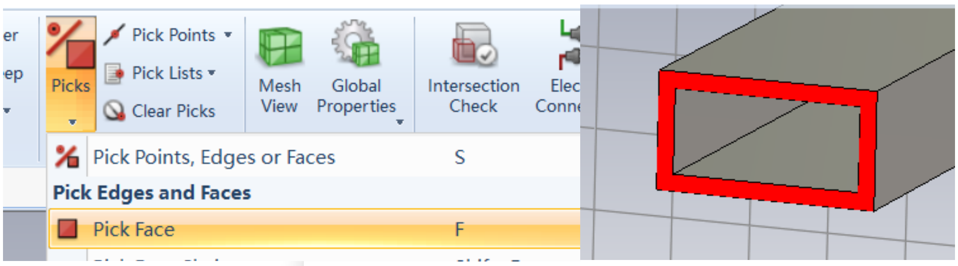
(2) Then, draw a brick on the outside of it, and the size of X and Y (width and height) should be slightly larger.

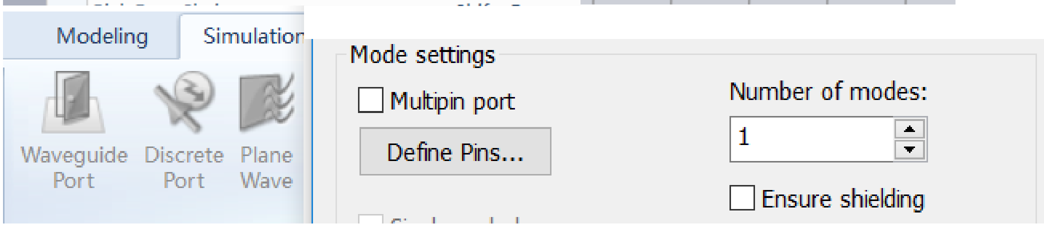


(3) In the component list on the left, select the larger brick (Solid2 here), click modeling menu ->Boolean -> subtract, follow the instructions to select the smaller brick (solid1 here), and press enter to obtain a vacuum rectangular waveguide through Boolean operation.

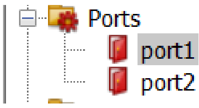


(4) Add Waveguide port: Select Pick Face and double-click the waveguide opening. Then click Simulation > Waveguide Port, set the Number of Modes to 1, that is, the modulus is 1. Do the same for the opening on the other side.

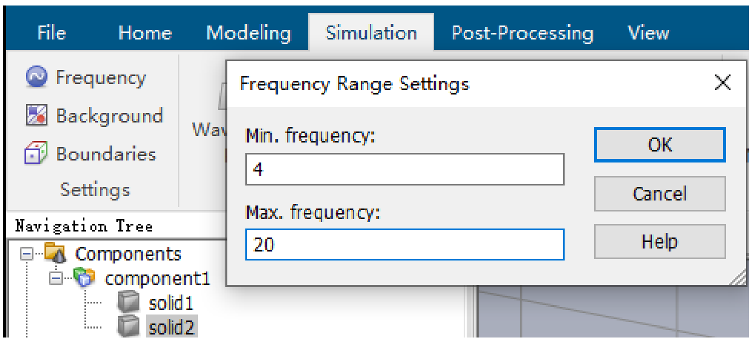


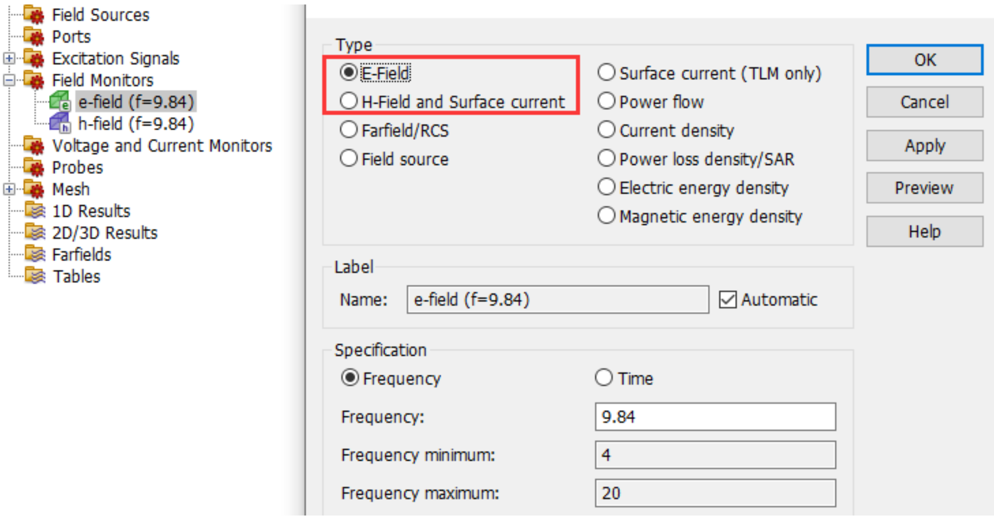


Finally, two ports are obtained, which are the excitation sources of waveguide.

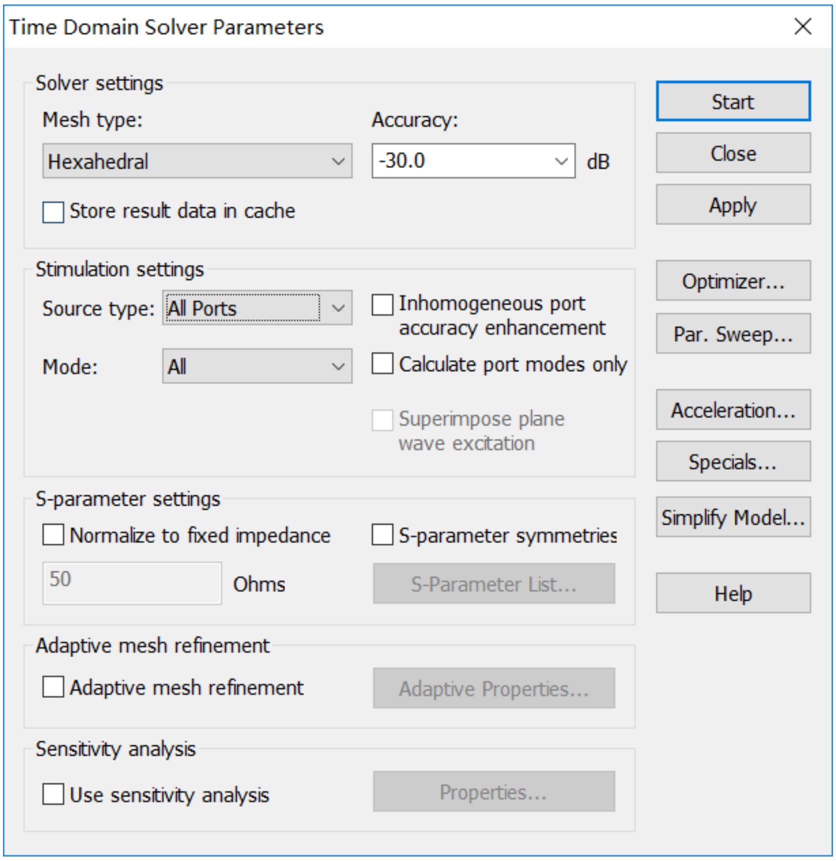


(5) Add Field Monitor: The experiment requires adding E-field monitor and H-field monitor, and setting the corresponding detection frequency. Click Simulation-> Frequency Range setting, setup proper frequency to ensure that the detection frequency is within the sweep range.



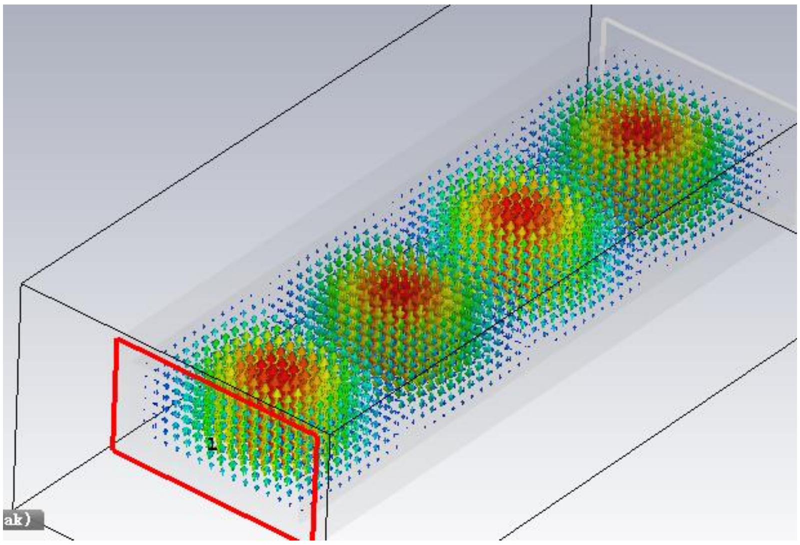


(6) Run simulation: Click Simulation ->setup solver, click start to start the operation without changing the parameters.



Here, Source Type – All Ports represents that all excitation sources are excited separately, and Mode –All is the modulus set for all excitation sources (previously set as 1). The simulation results are as follows:

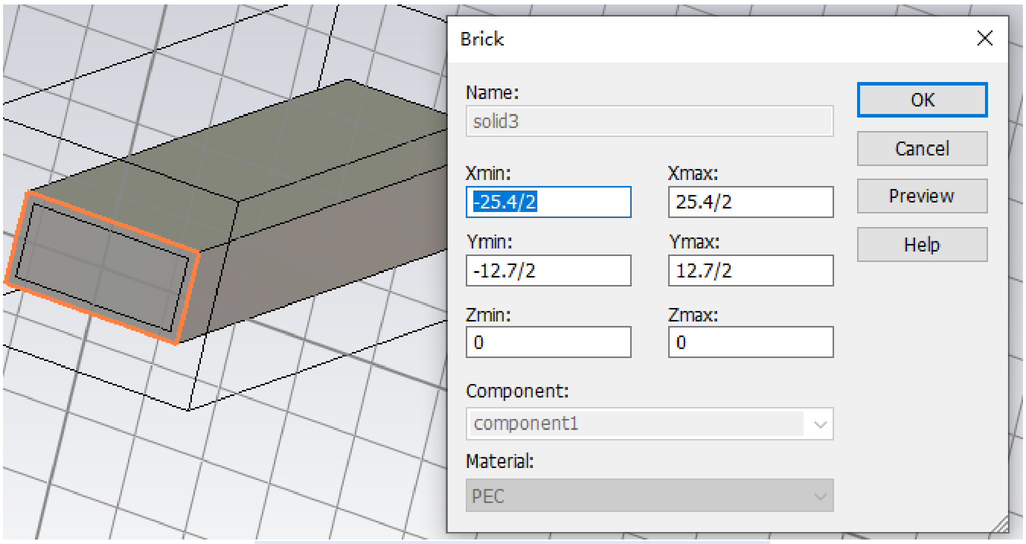
(E-field only)

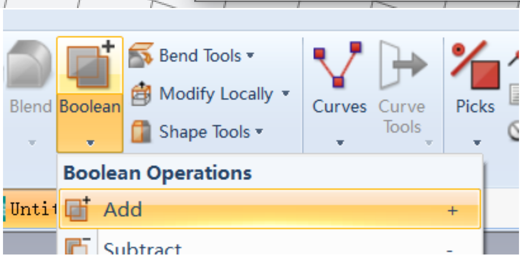


Understand and build coaxial-waveguide converter case 1

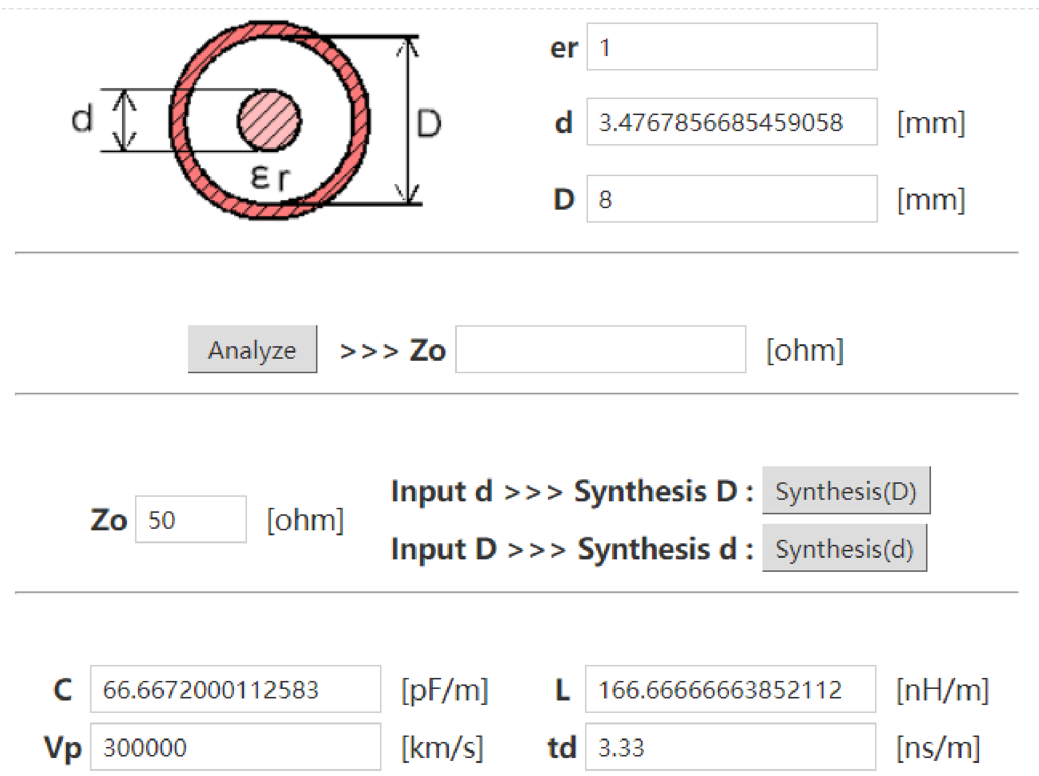
TEM wave propagates along the coaxial line, and the cut-off frequency of TEM wave is 0. However, coaxial lines support both the propagation of TE and TM, which are usually high order. In order to avoid the propagation modes superposition of different propagation constants, simultaneous interpreting the propagation of higher modes, the size of coaxial cables is set up, and the frequency also needs to be limited by the cut-off frequency of the lowest order waveguide mode.

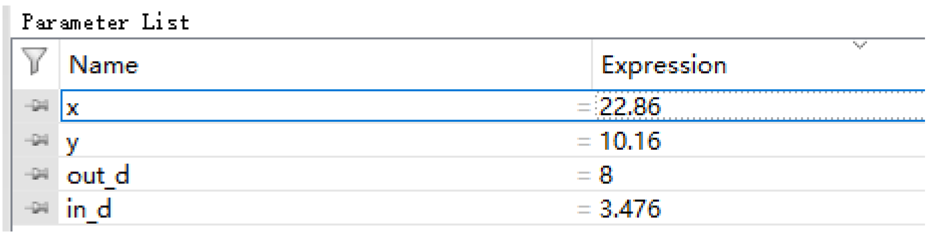
(1) Create a new project and build a rectangular waveguide model. The PEC board is used to seal one side port, and then Boolean add operation is used to merge.





(2) The characteristic impedance is 50 Ω, D = 8mm, eps_ r = 1.

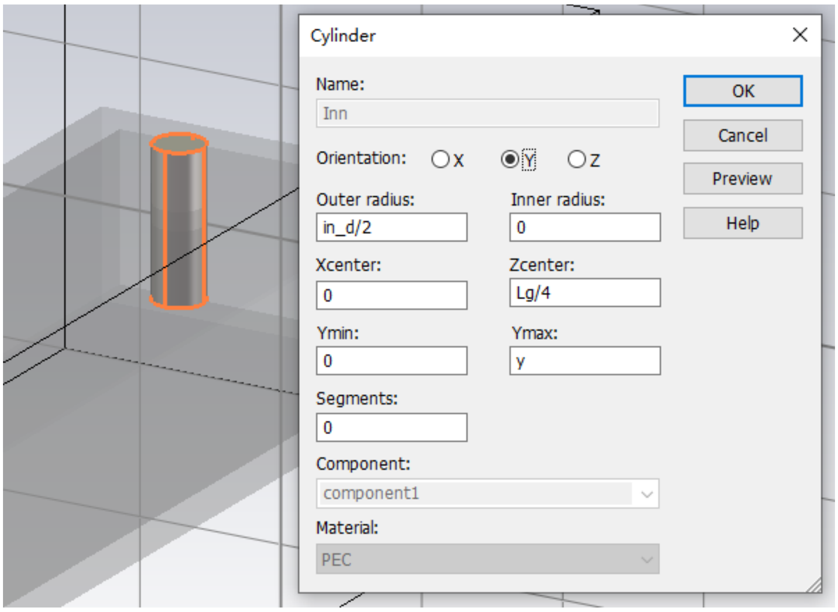



Parameter List

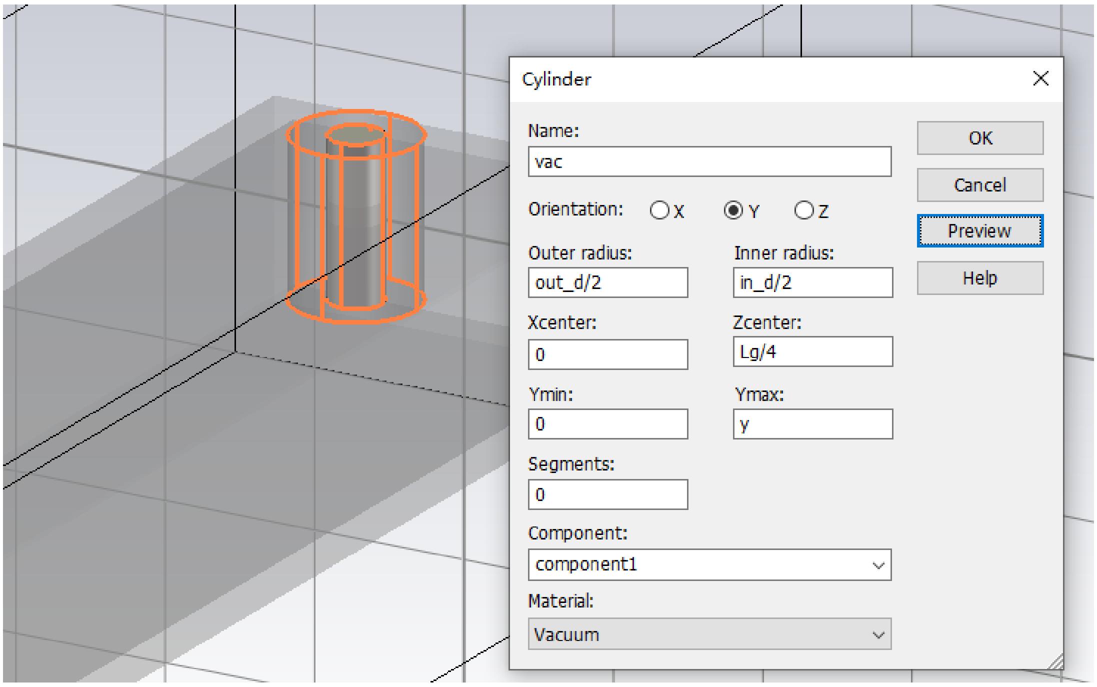
Name	Expression
x	22.86
y	10.16
out_d	8
in_d	3.476

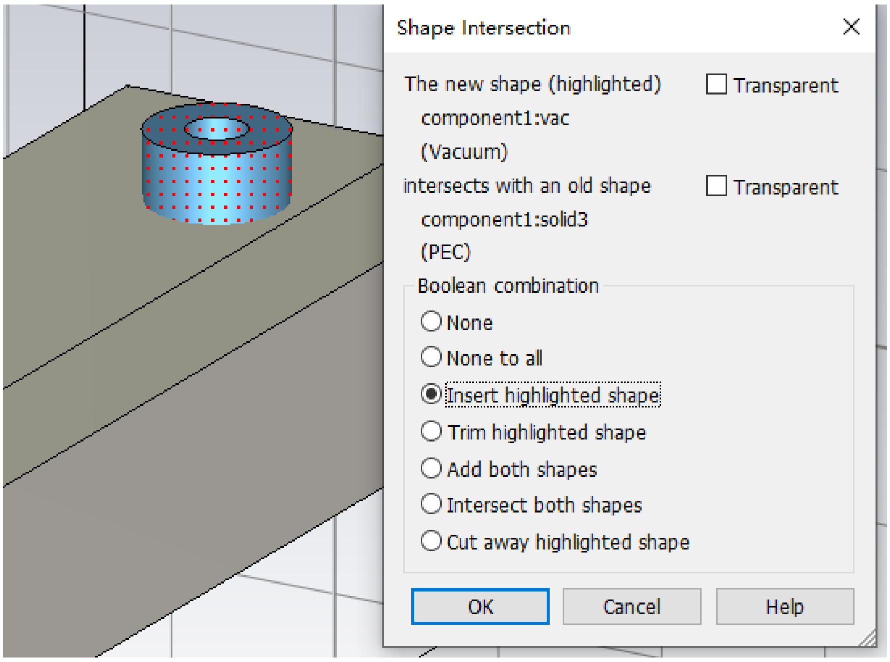
(3) Build coaxial line model: we need to build a coaxial line model by three steps.

1) Firstly, the inner central cylinder is drawn, where Lg is the guided wavelength, which will be mentioned in the subsequent experimental requirements and needs to be calculated. Here the parameter is used instead. The coaxial line is centered in the X direction, $Z= \lambda g/4$ and embedded in the waveguide.

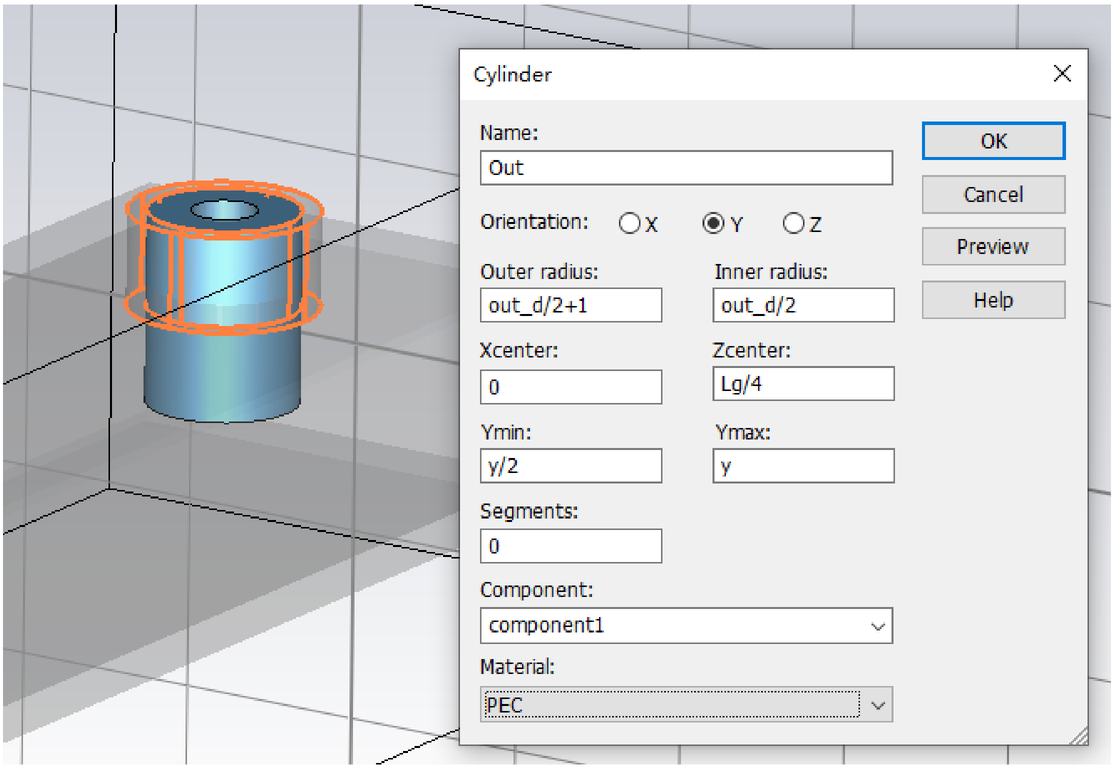


2) Then draw the middle vacuum layer, and select Insert highlighted space in the pop-up menu due to structure coincidence, which means to remove the overlap between rectangular waveguide material(PEC) and vacuum layer.



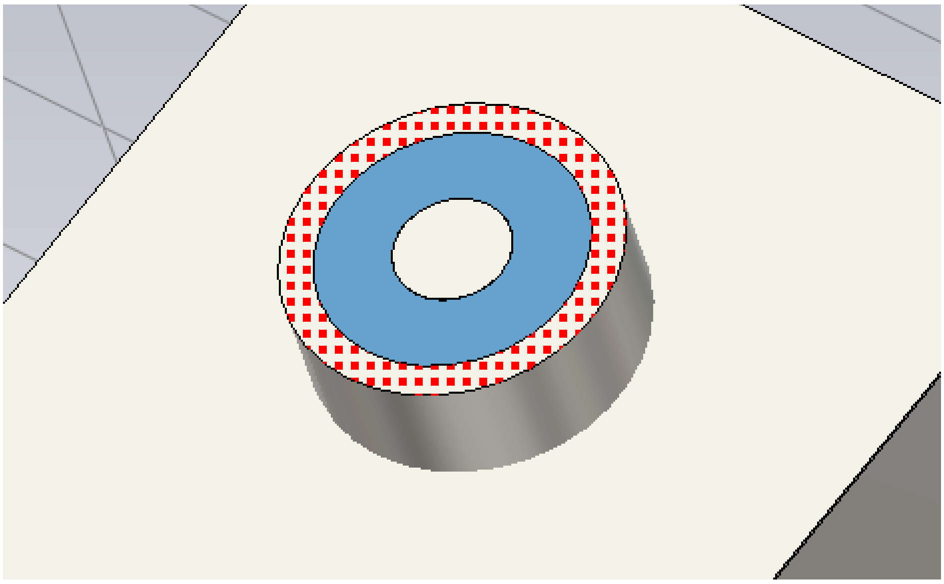


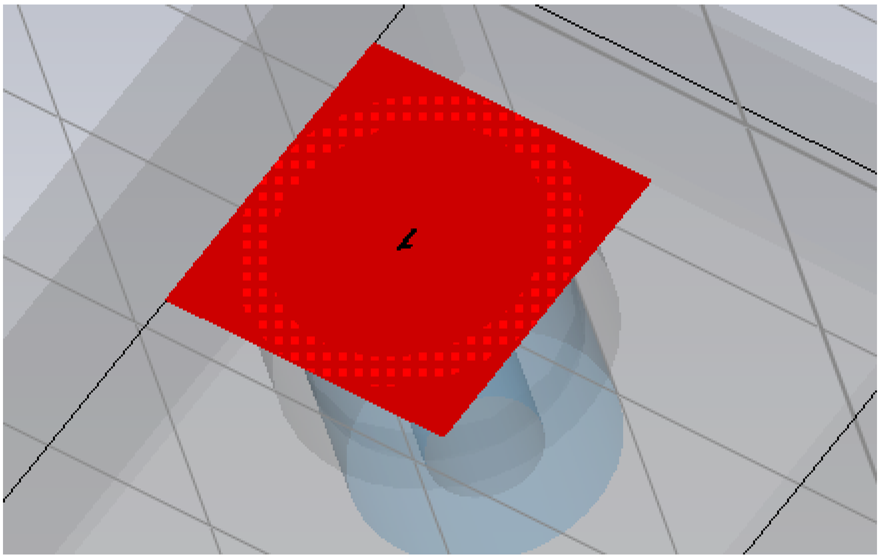
3) Finally, draw the outer circle.



(4) Add Port and Field Monitor to simulate

Select the surface as shown in the figure below, add Waveguide Port, add E & H Field Monitor according to the previous example, and click Setup Solver to perform the operation.





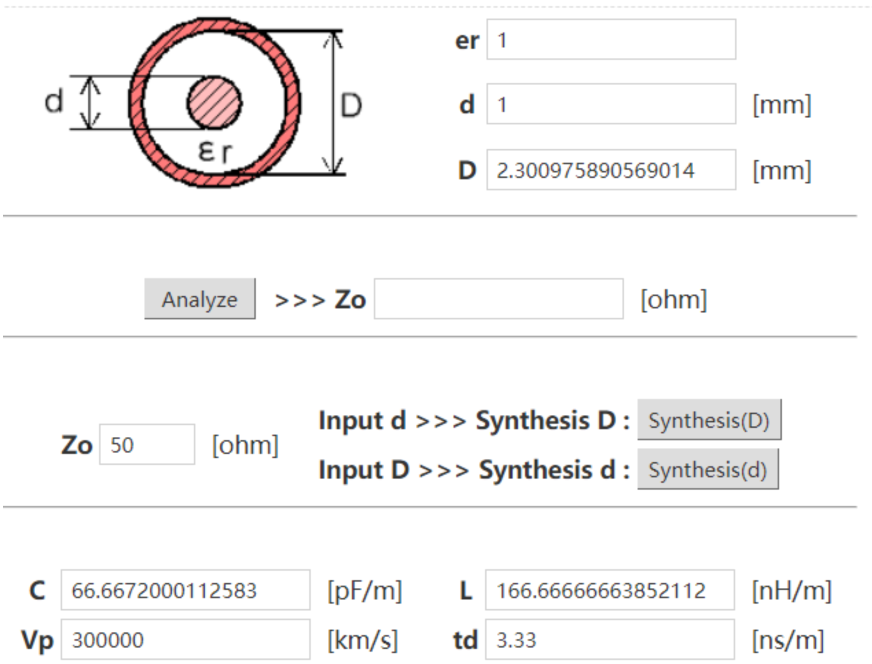
Understand and build coaxial-waveguide converter case 2

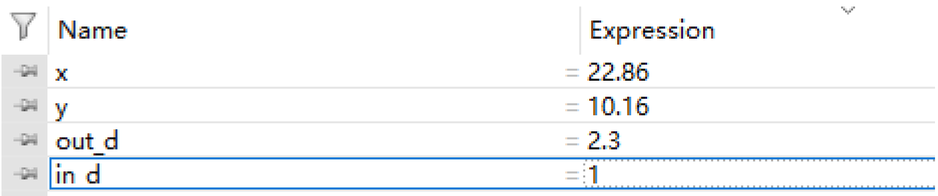
It can be seen from the above example that we have built a coaxial rectangular waveguide converter to convert the TEM wave of coaxial line to TE10 mode in rectangular waveguide. Its model is that the outer conductor of the coaxial line is connected with the wide wall of the rectangular waveguide, and the extension of the inner conductor is inserted into the waveguide to form a small radiation antenna, which excites TE10 mode in the waveguide.

Next, we need to design and build a coaxial rectangular waveguide converter to excite TE20 mode in the waveguide.

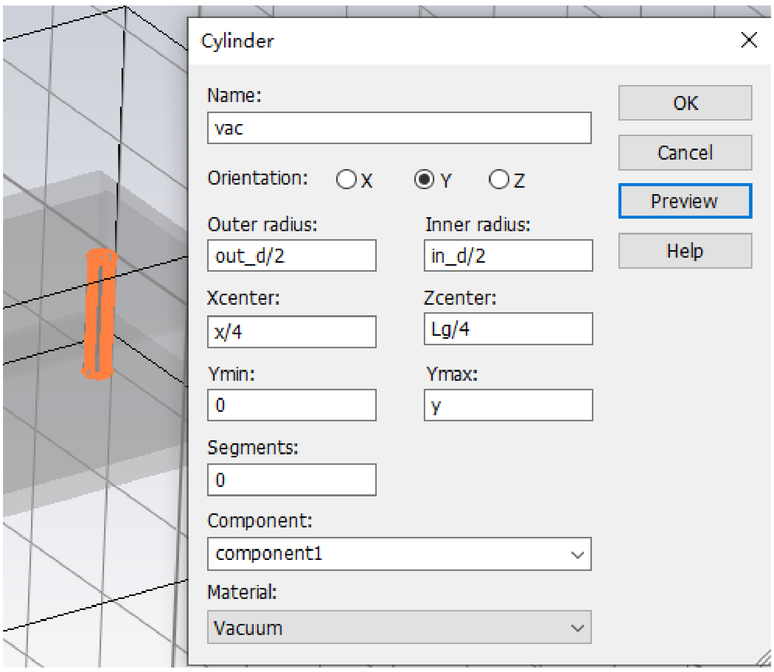
1. New or follow the previous project to build a rectangular waveguide model.

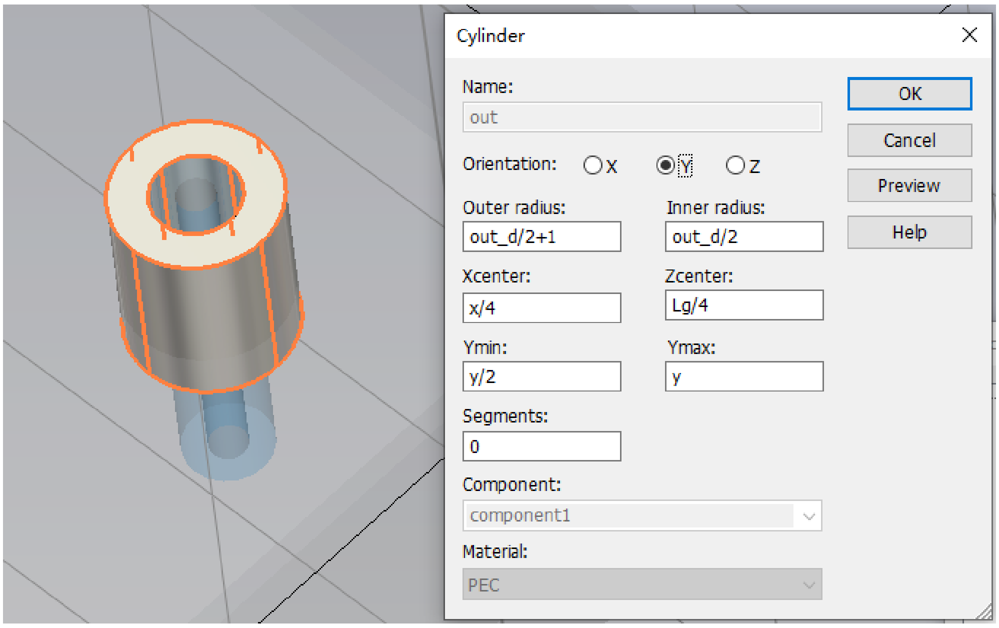
The size of the coaxial line is as follows, and the smaller size is used here. Here we use two coaxial lines, plus two excitations.



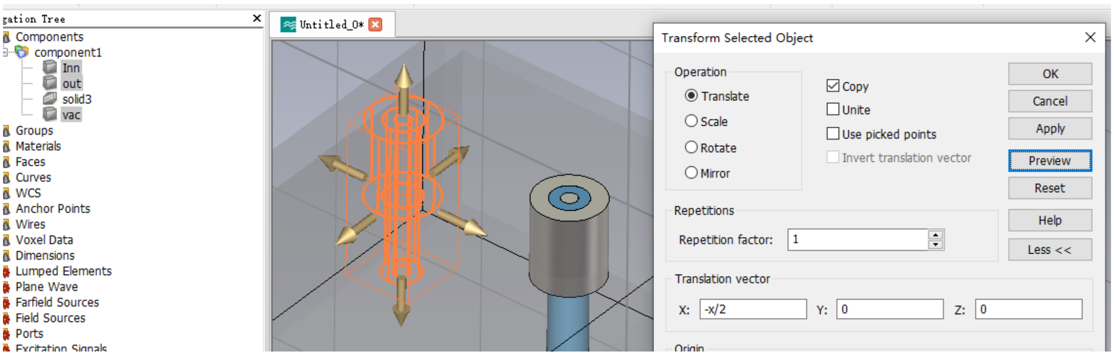


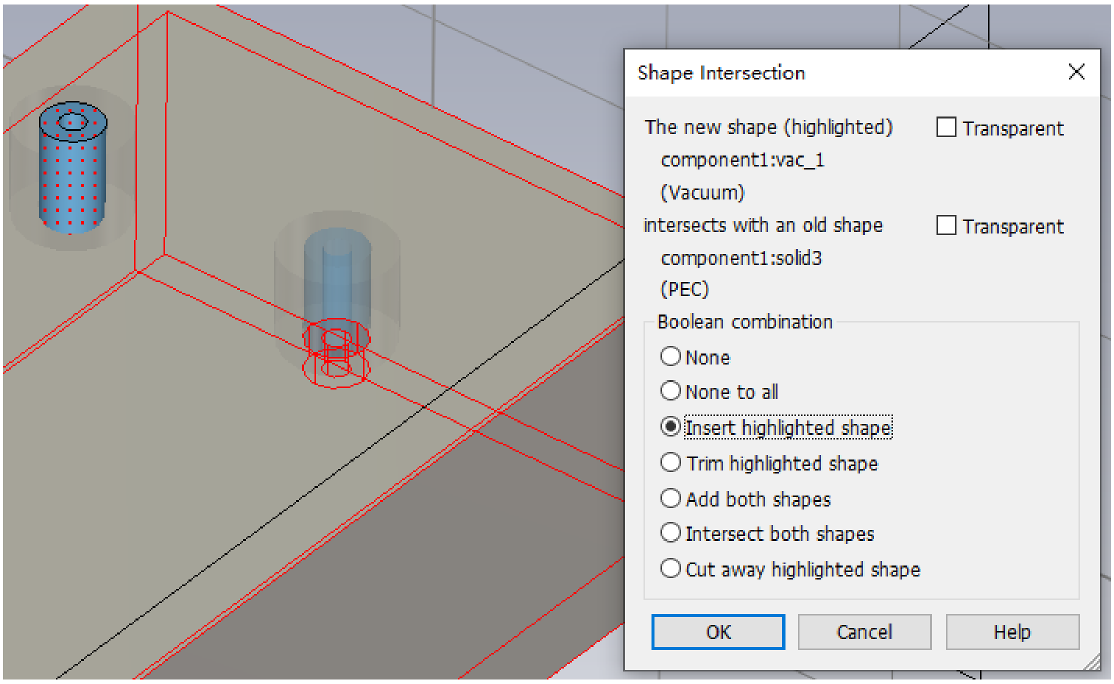
2. Draw one coaxial line according to the method of the previous example, and then draw another one by copying. Note that the position of the coaxial line should be at the quartering point of the x-axis. Note that the mode of excitation changes now, so the guided wavelength decreases λg also changed. In the example, although Zcenter still inputs Lg /4, Lg has been changed.



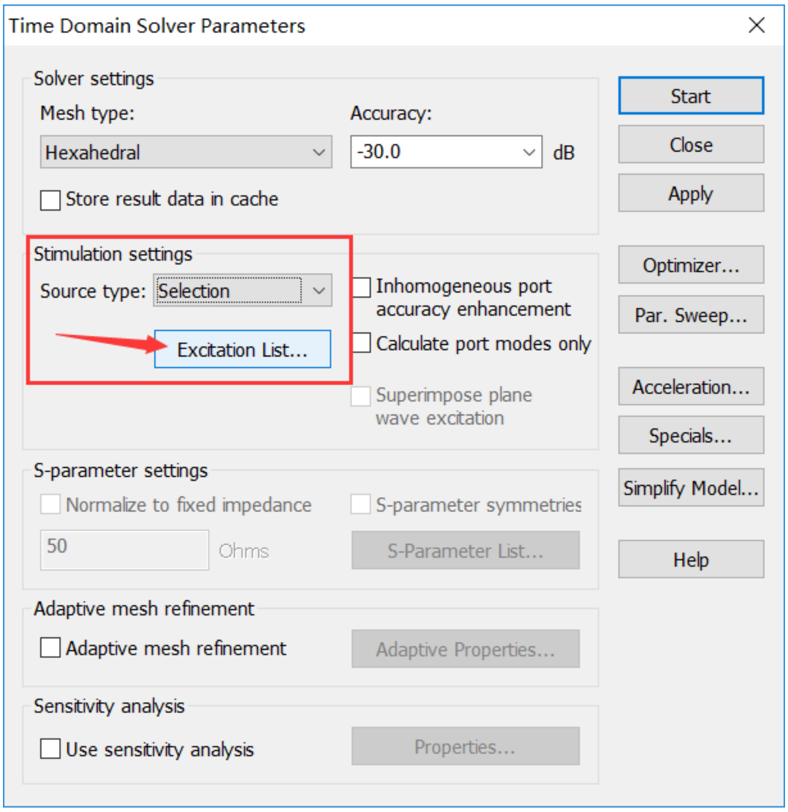


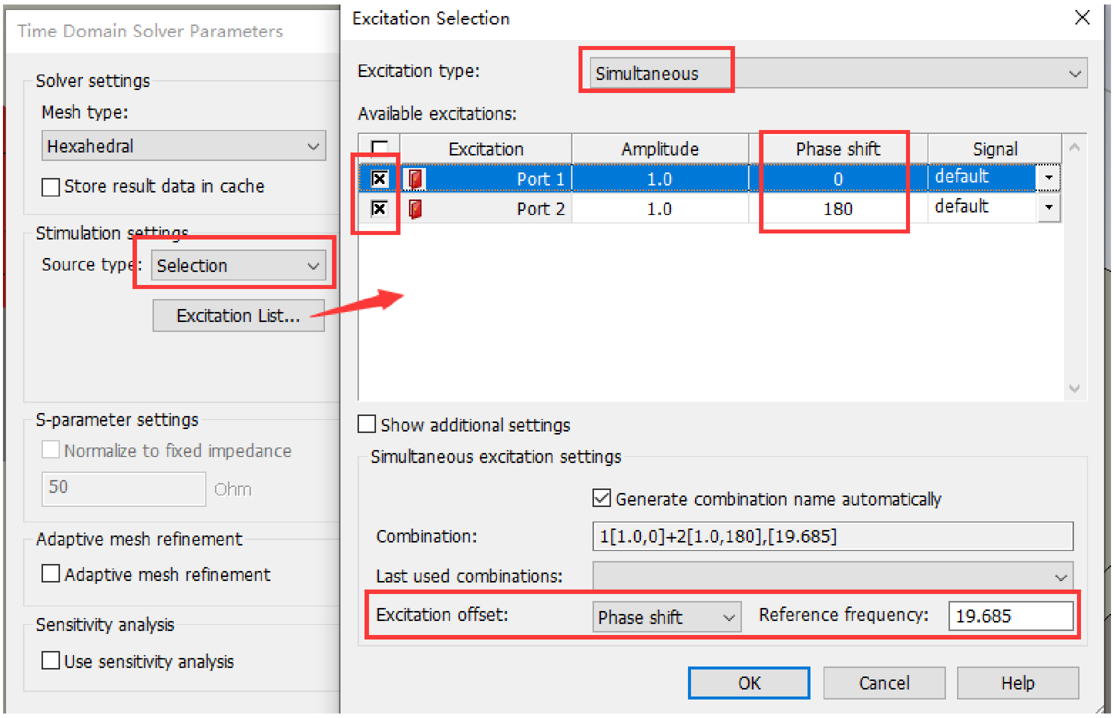
3. After drawing one, press and hold Ctrl to select three Components of the coaxial line at the same time, click Modeling-> transform, and check Copy to move out another coaxial line. Select Insert Highlighted Space in the pop-up menu due to structure coincidence, which means to remove the overlap between rectangular waveguide material(PEC) and vacuum layer.





4. Use the same method as the above example to add excitation on the two coaxial lines, and set number of modes to 1. Then click Setup Solver to make the following settings, and then click Start to calculate.





It may take a long time to calculate and need to wait patiently. But if the time is too long, please check whether the operation is wrong.

Lab Requirement

Refer to the above process, complete the following:

1. Establish a WR90 rectangular waveguide model. Calculate the guided wavelength λg and cut-off frequency fc of TE10 mode. Simulate and observe the patterns of 1.5 * fc and 2.5 * fc The z-direction length of the waveguide is set as 2 times the guided wavelength at 1.5 * fc (no need to change in later simulations). The excitation sources are placed at both ends of the waveguide, and field monitors are added to show the patterns of electric field and magnetic field on the cross sections of xOy, xOz and yOz.

2. Use the rectangular waveguide model in question 1, it is required to fill the waveguide model with a lossless material whose relative permittivity is set to be 4 (eps_r=4). Calculate the cut-off frequency fc of TE10 mode and simulated at 1.5 * fc. Show the pattern of electric field and magnetic field on the cross section of xOy, xOz, yOz.

3. Use the rectangular waveguide model in question 1, Calculate the cut-off frequency fc of TE20 mode and simulated at 1.5 * fc. Show the pattern of electric field and magnetic field on the cross section of xOy, xOz, yOz.

4. The rectangular waveguide model fed by coaxial line is established. Using the rectangular waveguide model of the first question and the cut-off frequency fc, the waveguide port with Z = 0 is sealed, and the characteristic impedance Z0 = 50Ω is added， The coaxial line with d =

8 mm is embedded in half of the waveguide size in Y direction, the X direction is located in the center of the waveguide, and the Z direction is located in Z direction= λg / 4, trying to explain why the coaxial line position should be set in this way. Show the electric field pattern on z = 3 / 8* λ g， 1/2* λ g， λ g， 2* λ and the cross section of xOz, then try to analyze and explain.

5. The rectangular waveguide model fed by coaxial line is established. Using the rectangular waveguide model of the first question, the waveguide port with Z = 0 is sealed and the characteristic impedance of Z0 = 50Ω is added， When d = 1 mm coaxial line feed, TE20 mode is required to be generated in rectangular waveguide. The coaxial line is embedded in half of the waveguide size in the Y direction, the X direction is located in the center of the waveguide, and the Z direction is located in the Z direction= λ g/4。 Show the pattern of electric field on the cross section of xoz and the pattern on waveguide port, try to analyze and explain.

The calculation process should be given for all calculations.