**DAYALBAGH EDUCATIONAL INSTITUTE,
DAYALBAGH, AGRA**

Manual

Experiment 8

Design and Characterization of Coplanar Waveguide

Experiment 8

Objective:

To design the Coplanar Waveguide at 1.5 GHz

1. Calculate the length and width of Coplanar Waveguide at 1.5 GHz

To simulate the Coplanar Waveguide

1. Specify the Coplanar Waveguide parameter
2. Define the geometric modal
3. Define the material data and boundary conditions
4. Run the simulation
5. Analyze the simulation results

Requirement:

1. Computer facility
2. EMgine Simulation Software

Theory:

A representation of coplanar waveguide is shown in figure1. At first glance, it resembles microstrip construction. It has a single circuit board, just like microstrip; it has the circuit traces on the top of the board, just like microstrip; and it has air over the top of the circuit board, just like microstrip. When you look at it a little closer, however, you see some very distinct difference. In microstrip construction, there is a circuit trace on the top of the board material of a certain width and thickness. There is also a complete ground plane on the reverse side of the board. In a coplanar waveguide, there is still a circuit trace on top of the board that is a certain width and thickness, but there are also ground planes on both sides of the circuit trace and, as can be seen in figure 1, there is also ground plane on the bottom of the circuit board. Ground plane on both sides of the circuit trace is where this type of transmission line structure get its name. ***A conductor surrounded by ground "guides" the electromagnetic wave down the transmission line.***

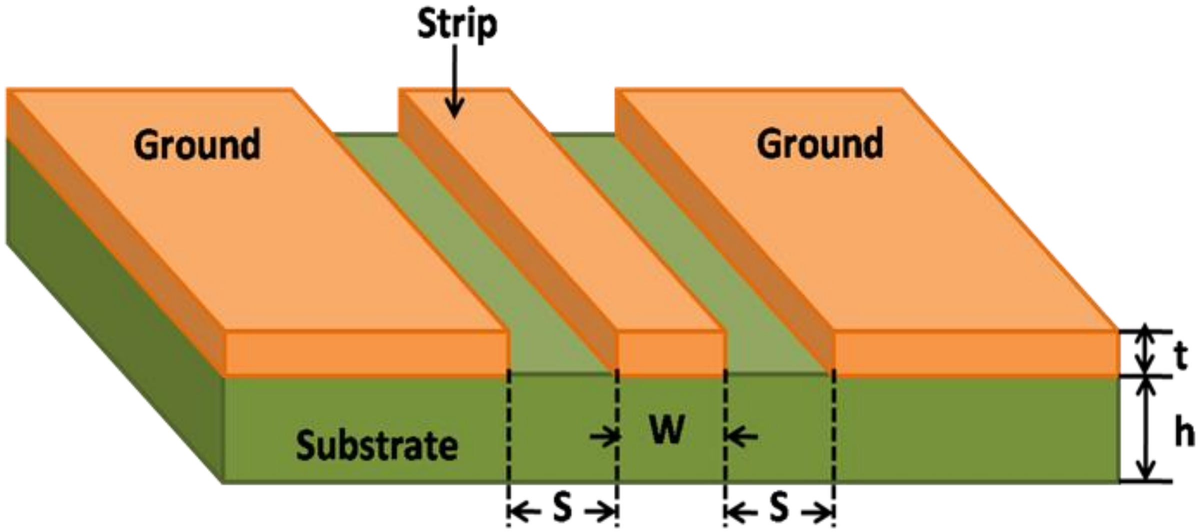


Figure 1: Coplanar Waveguide Structure

A coplanar waveguide is a planar transmission structure for transmitting microwave signals (f>300MHz). A conventional CPW on a dielectric substrate consists of a center strip conductor with semi-infinite ground planes on either side as shown in Figure 1. This structure supports a quasi-TEM mode of propagation. The CPW offers several advantages over conventional microstrip line: First, it simplifies fabrication: second, it facilitates easy shunt as well as series surface mounting of active and passive devices: third, it eliminates the need for wraparound and via holes, and fourth, it reduces radiation losses. In addition a ground plane exists between any two adjacent lines, hence cross talk effects between adjacent lines are very week. As a result, CPW circuits can be made denser than conventional microstrip circuits. These, as well as several other advantages, make CPW ideally suited for MIC (Microwave Integrated Circuits) as well as MMIC(Monolithic Microwave Integrated Circuits) applications.

The coplanar waveguide (CPW) proposed by C. P. Wen in 1969 consisted of a dielectric substrate with conductors on the top surface. The conductors formed a center strip separated by a narrow gap from two ground planes on either side. The dimensions of the center strip, the gap, the thickness and permittivity of the dielectric substrate determined the effective dielectric constant (e_{eff}), characteristic impedance (Z_0) and the attenuation (a) of the line. This basic structure has become known as the conventional CPW.

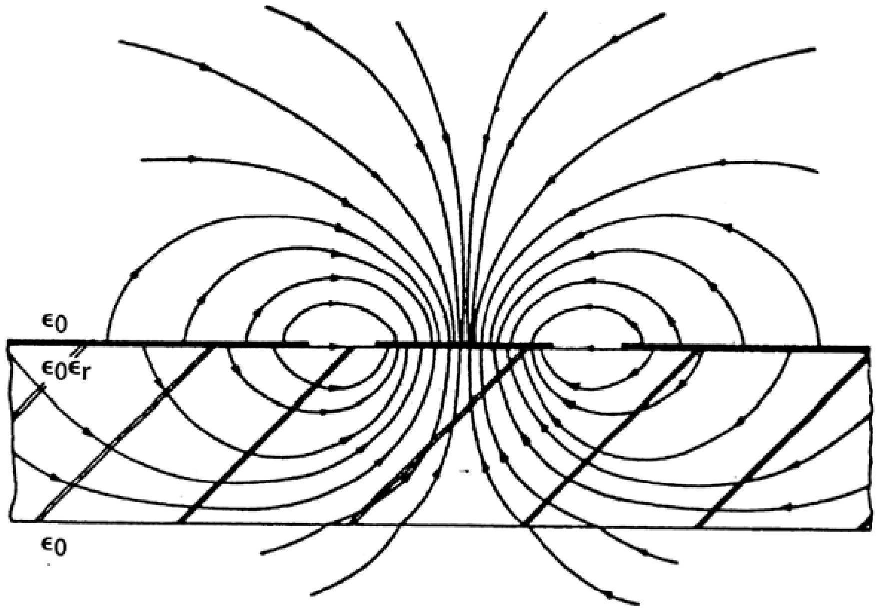


Figure 2 Field Distribution in Coplanar Waveguide

Figures 2 and 3 illustrate the computed electric field and magnetic field, respectively, in the cross section of the coplanar waveguide. It is observed that the electric-field lines extend across the slot while the magnetic-field lines are perpendicular to the air-dielectric interface in the slot. The electric and magnetic field in the right half of the structure are in a direction opposite to the electric and magnetic field in the left half of the structure. Furthermore part of the magnetic-field lines encircles the center conducting strip separating the two slots. Hence it should be possible to realize CPW circulators whose function is dominated by the transverse magnetic field component. The longitudinal view in Figure 2 shows that in the air regions the magnetic-field lines curve and return to the slot at half-wavelength intervals. Consequently a wave propagating along the structure has an elliptically polarized magnetic field. Hence it should be possible to successfully exploit the elliptically polarized magnetic field in the design of CPW resonance isolators and differential phase shifters.

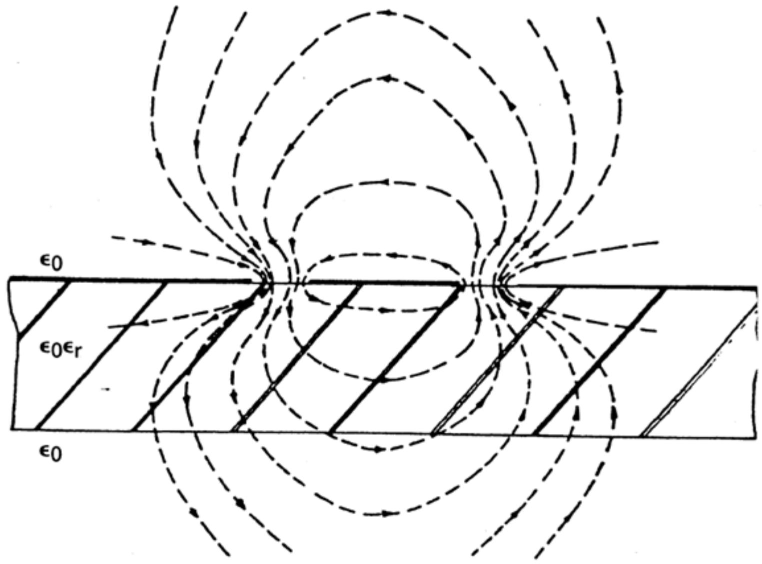


Figure 3: Computed magnetic-field distribution in the cross section (x_0 plane).

Formula Used:

The coplanar waveguide have a single plane waveguiding structure. The circuit is printed on one side in one plane, the dimension of the slot width and strip width is small, which may realize the circuit as hybrid circuit. Because of the small strip cross sectional area power transfer is also limited, which causes the higher attenuation in the device. The coplanar structure is surrounded by conductor with ground potential hence the structure leads the decoupling behavior of neighboring transmission line. The dielectric region of the structure should be thick because field can lack from the backside of the device. Generally, the thickness of the substrate should be one or two time the width of the slots. It is obvious that the finite thickness of the substrate will influence the dispersion characteristics of the transmission line. The characteristic impedance of the coplanar transmission line can be approximately derived by applying conformal mapping:

$$Z_O = \frac{30\pi}{\sqrt{\varepsilon_{eff}}} \frac{K'(k)}{K(k)} \quad \Omega$$

And *K/K'* is given by:

$$\frac{K(k)}{K'(k)} = \frac{\pi}{\ln\left(2\frac{1+\sqrt{k'}}{1-\sqrt{k'}}\right)} \qquad for \quad 0 \le k \le 1/\sqrt{2}$$

$$\frac{K(k)}{K'(k)} = \frac{1}{\pi}\ln\left(2\frac{1+\sqrt{k}}{1-\sqrt{k}}\right) \qquad for \quad 1/\sqrt{2} \le k \le 1$$

And effective dielectric constant can be found by

$$\varepsilon_{eff} = \frac{\varepsilon_r + 2}{2}\left\{\begin{array}{l} \tanh\left[1.785\log\left(\frac{h}{w}\right)+1.75\right] \\ +\frac{kw}{h}\left[0.04-0.7k+0.01(1-0.1\varepsilon_r)(0.25+k)\right] \end{array}\right\}$$

Given Parameters:

Frequency f = 1.5 GHz

Substrate Thickness d = 1.1 mm

Substrate Permittivity ε_r = 5.5

Calculate:

Length of Coplanar Waveguide L = ?

Width of Coplanar Waveguide W = ?

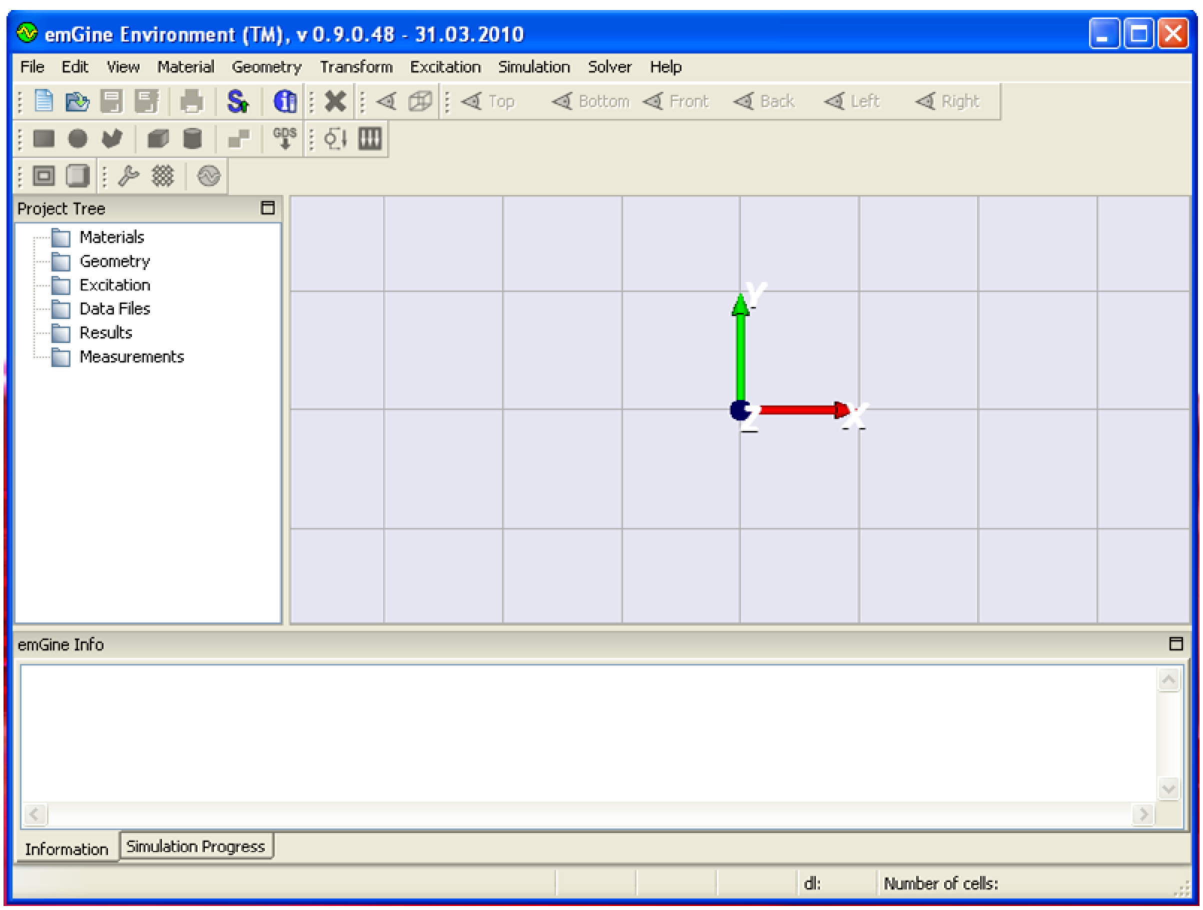
Procedure for Simulation:

Introduction and Model Dimensions

In this tutorial you will learn how to simulate planar devices. As a typical example for a planar device, you will analyze a coplanar waveguide. The following explanations on how to model and analyze this device can be applied to other planar devices, as well.

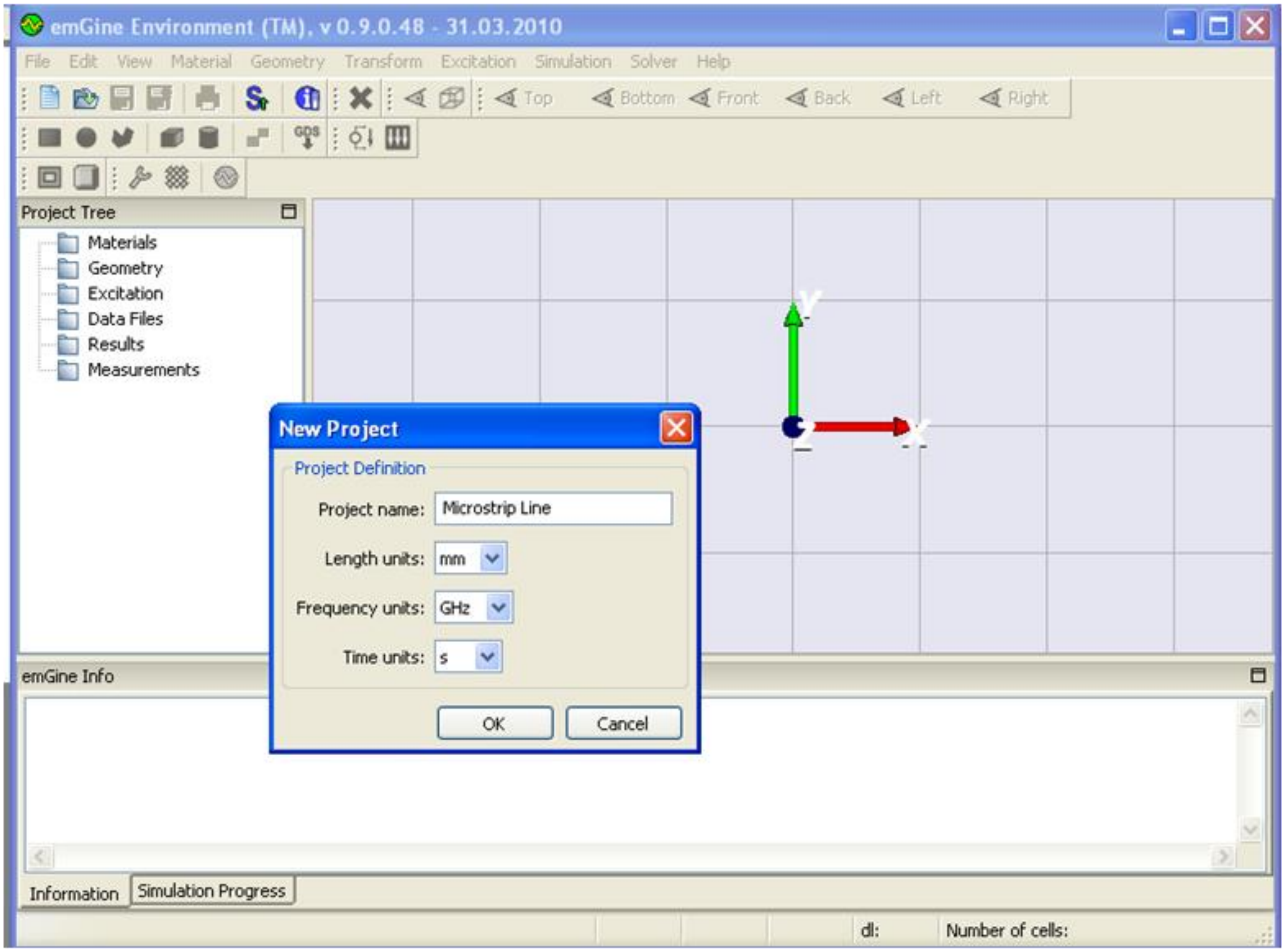
Geometric Construction Steps

This tutorial will take you step by step through the construction of your model, and relevant screen shots will be provided so that you can double-check your entries along the way. Download the given link of emGine Environment. Go to emGine in the program file and double click to open the simulator.

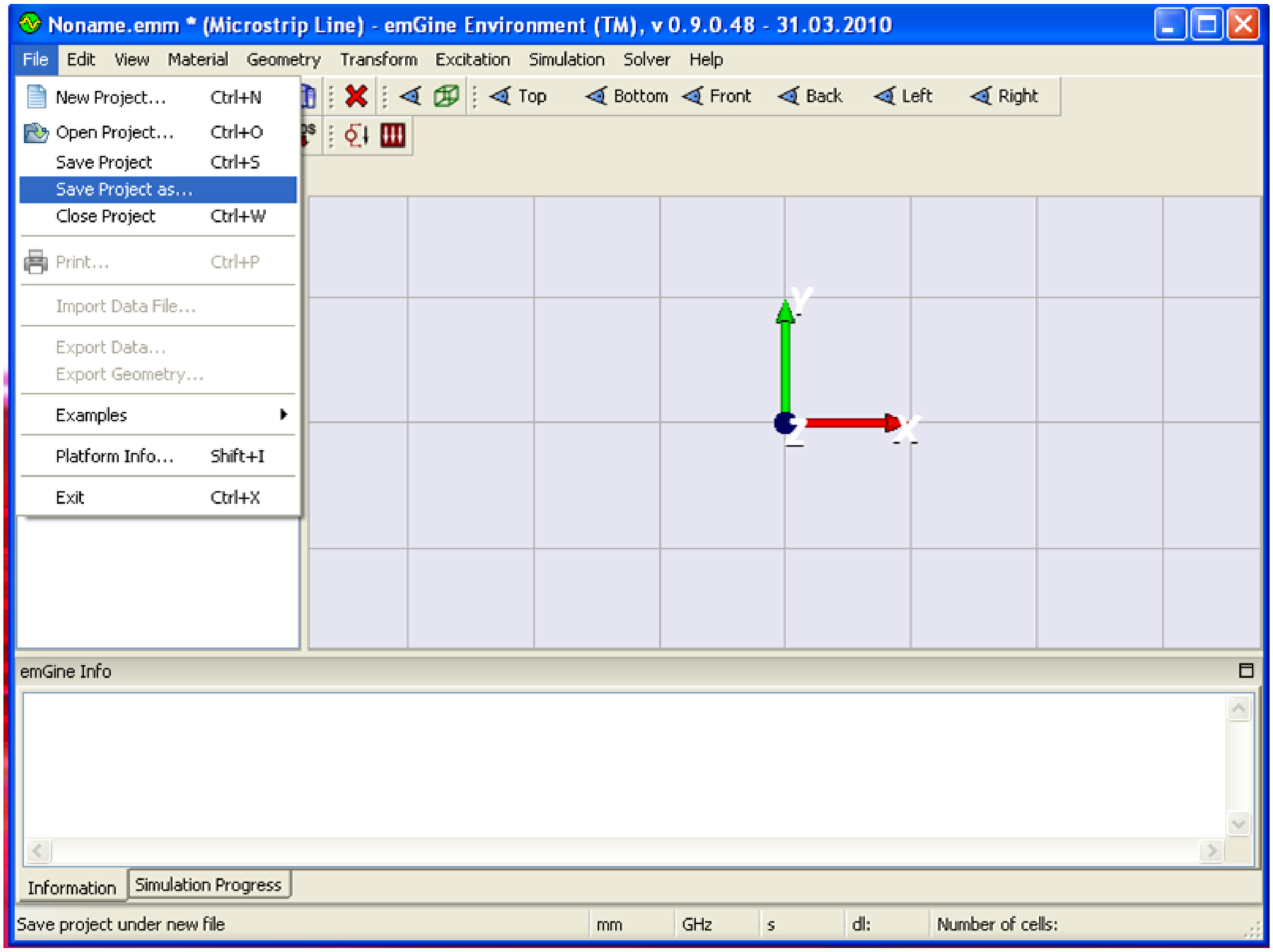


Select a Template

Once you have started emGin, go to file and click on new project a dialog box will open to give the appropriate name for the new project. You should set the units in mm, GHz and s and press ok.

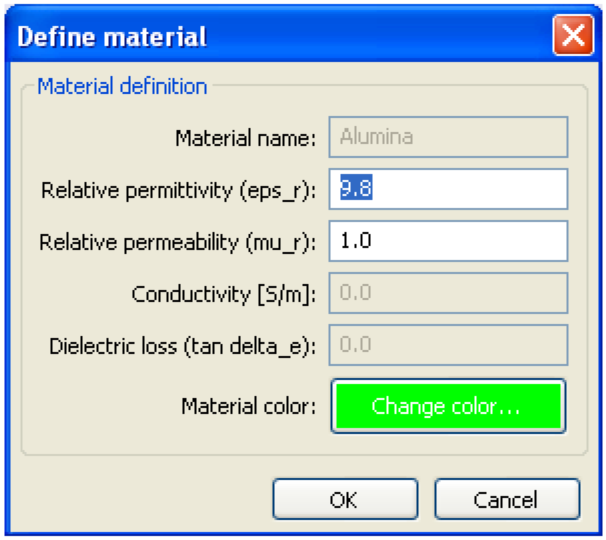


Now again go to file click on save project as and save your project at any location in my computer.



Set the Material Properties

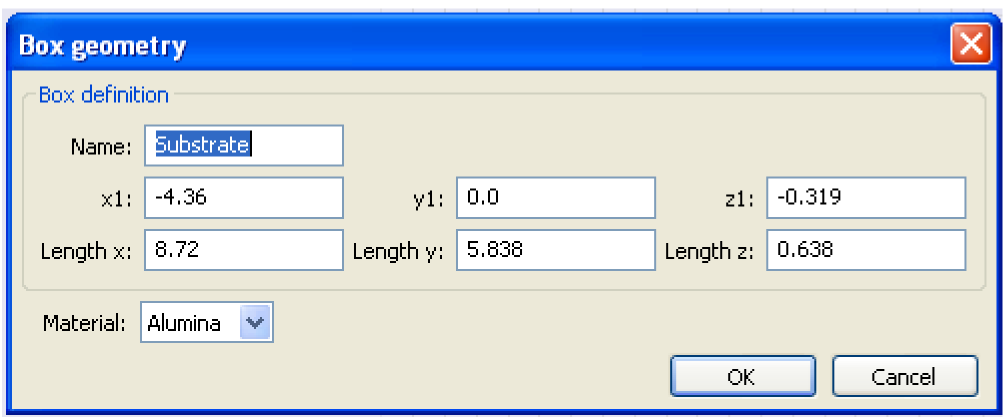
The next step is usually to set the material properties. In this dialog box you should define a new *Material name* (e.g. Alumina). Afterwards, specify the material properties in the *Epsilon* and *Mue* fields. Here, you only need to change the dielectric constant *Epsilon* to 9.8. Finally, choose a color for the material by pressing the *Change* color button. Your dialog box should now look similar to the picture below before you press the *OK* button.



Draw the Substrate Brick

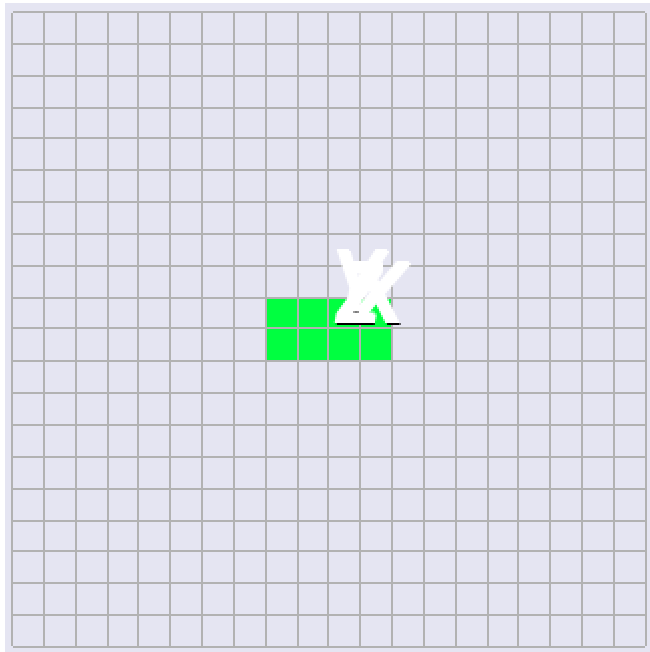
The first construction step for modeling a planar structure is usually to define the substrate layer. This can be easily achieved by creating a brick made of the substrates material. Please activate the brick creation mode (*Geometry - Box*).

When you are prompted to define the first point, you can enter the coordinates numerically by clicking Box that will open the following dialog box:



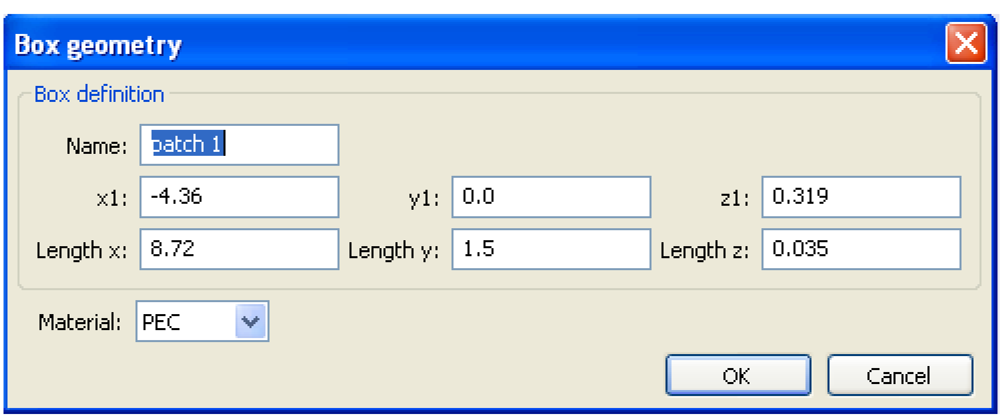
In this example, you should enter a substrate block. The transversal coordinates can thus be described by X 1= -4.36, Y = 0.0, Z 1= -0.319 for the first corner and give the calculated length X = 8.72, Y = 5.838, Z = 0.638 for creating the brick, assuming that the brick is modeled symmetrically to the origin. Please check all these settings carefully. If you encounter any mistake, please change the value in the corresponding entry field. You should now assign a meaningful name to the brick by entering e.g. substrate in the *Name* field.

The *Material* setting of the brick must be changed to the desired substrate material. Because no material has yet been defined for the substrate, you should open the layer definition dialog box by selecting Alumina from the *Material* dropdown list. Now in the brick creation dialog box you can also press the *OK* button to finally create the substrate brick. Your screen should now look as follows

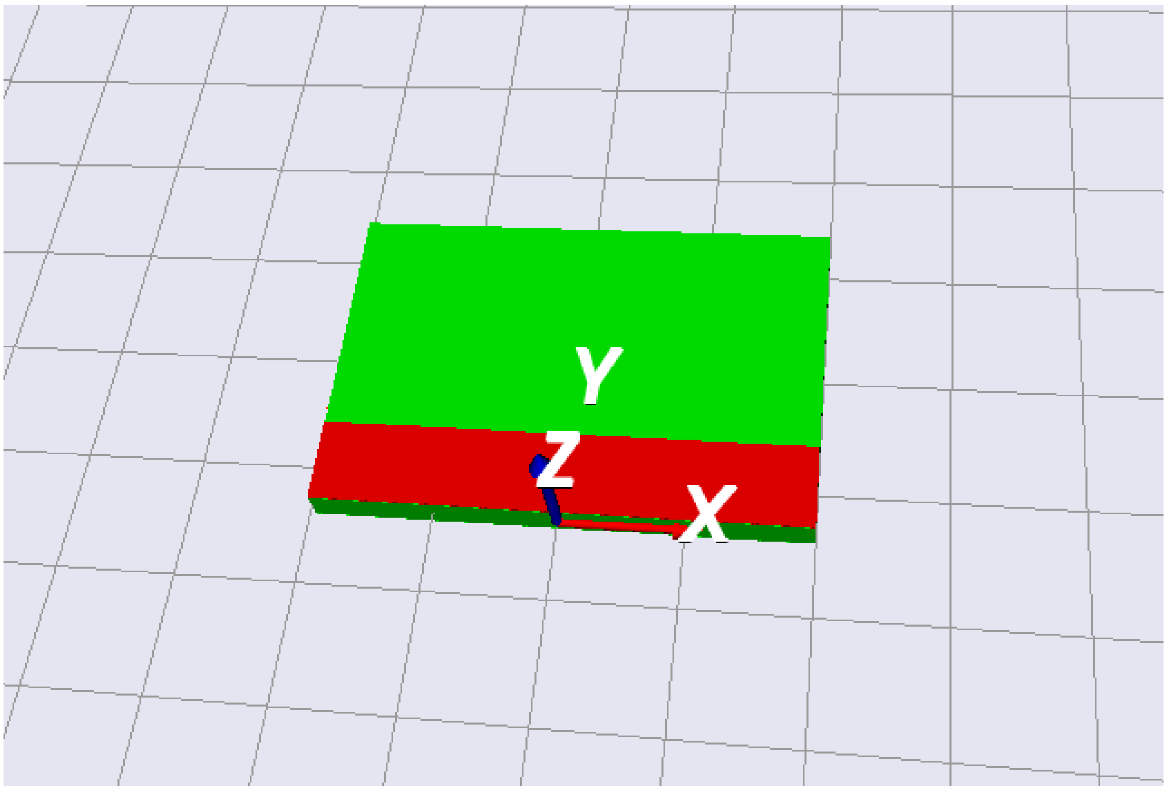


Model the Ground Plane

The next step is to model the first ground plane on top of the substrate. Therefore, you should again do the same process. For the dimensions of first ground plane over substrate, you should design the coplanar waveguide. The transversal coordinates can thus be described by X1 = -4.36 , Y1 = -0.0, Z1= 0.319 for the first corner and give the actual length as length X = 8.72, length Y = 1.5, length Z = .035 as you did above. You should now assign a meaningful name to the brick by entering e.g. patch 1in the *Name* field.

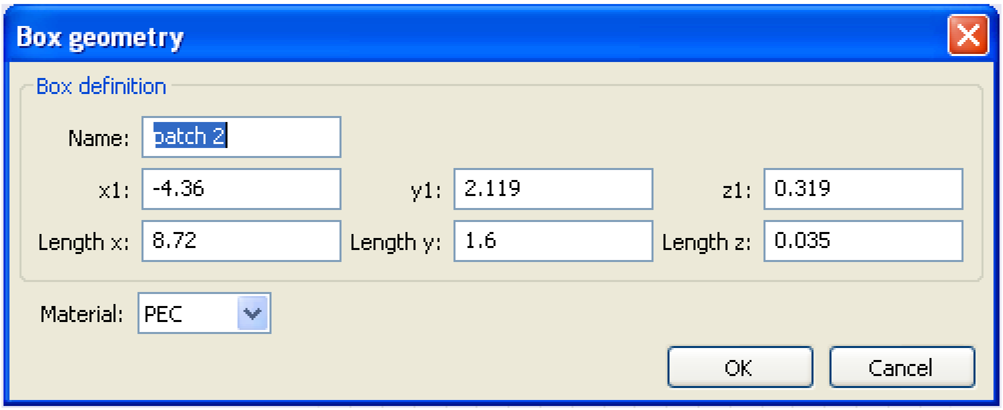


The *Material* setting of the brick must be changed to the desired material. Because no material has yet been defined for the coplanar waveguide, you should select the PEC as the material for patch 1 from the material drop down list and in the brick creation dialog box you can also press the *OK* button to finally create the first ground plane. Your screen should now look as follows

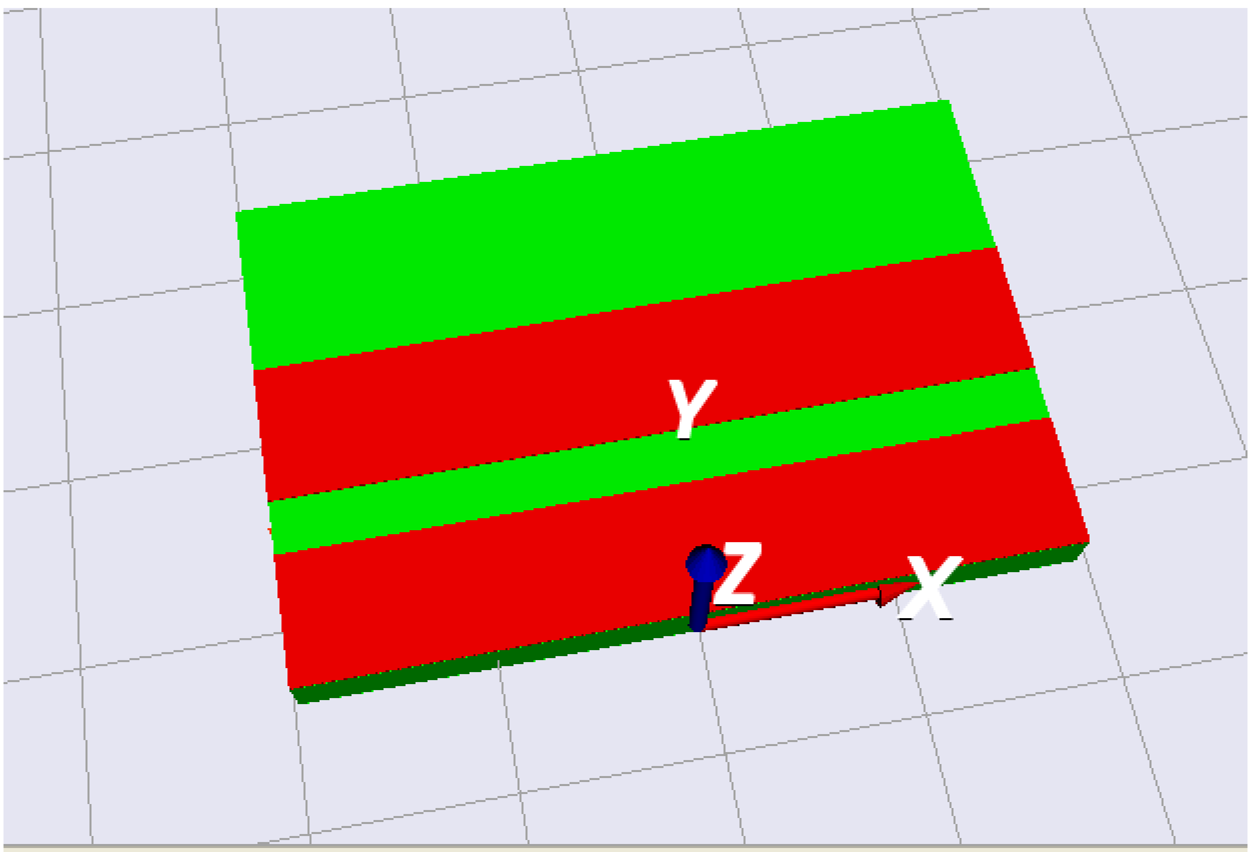


Model the Transmission Line

The next step is to model the transmission line above the substrate. Therefore, you should again do the same process. For the dimensions of ground plane below substrate, you should design the ground plane brick. The transversal coordinates can thus be described by X1 = -4.36, Y1 = 2.119, Z1=- 0.319 for the first corner and give the actual length as length X = 8.72, length Y = 1.6, length Z = -0.035 as you did above. You should now assign a meaningful name to the brick by entering e.g. patch 2 in the *Name* field.

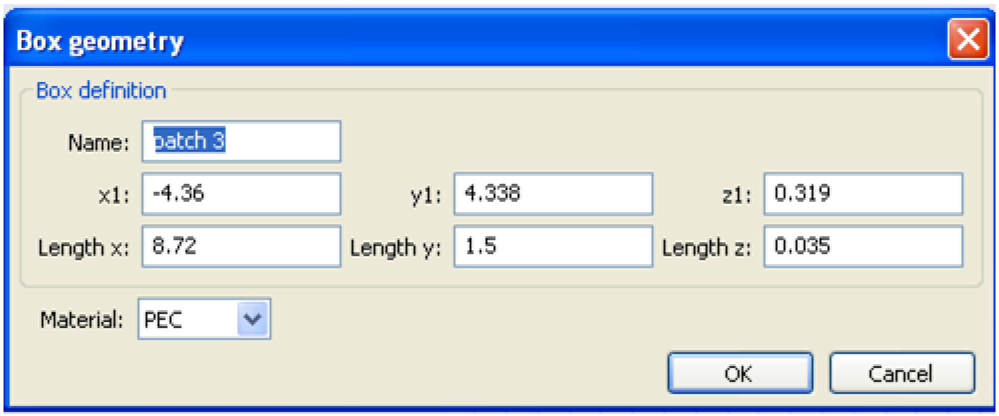


The *Material* setting of the brick must be changed to the desired ground plane. Because no material has yet been defined for the patch 2, you should select PEC as the material for patch 2 from the material drop down list and in the brick creation dialog box press the *OK* button to finally create the ground plane. Your screen should now look as follows

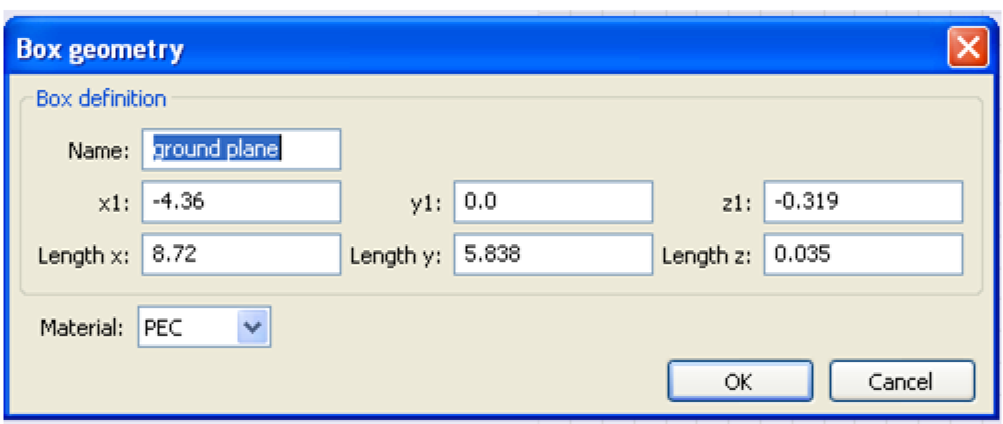


Model the Ground Plane

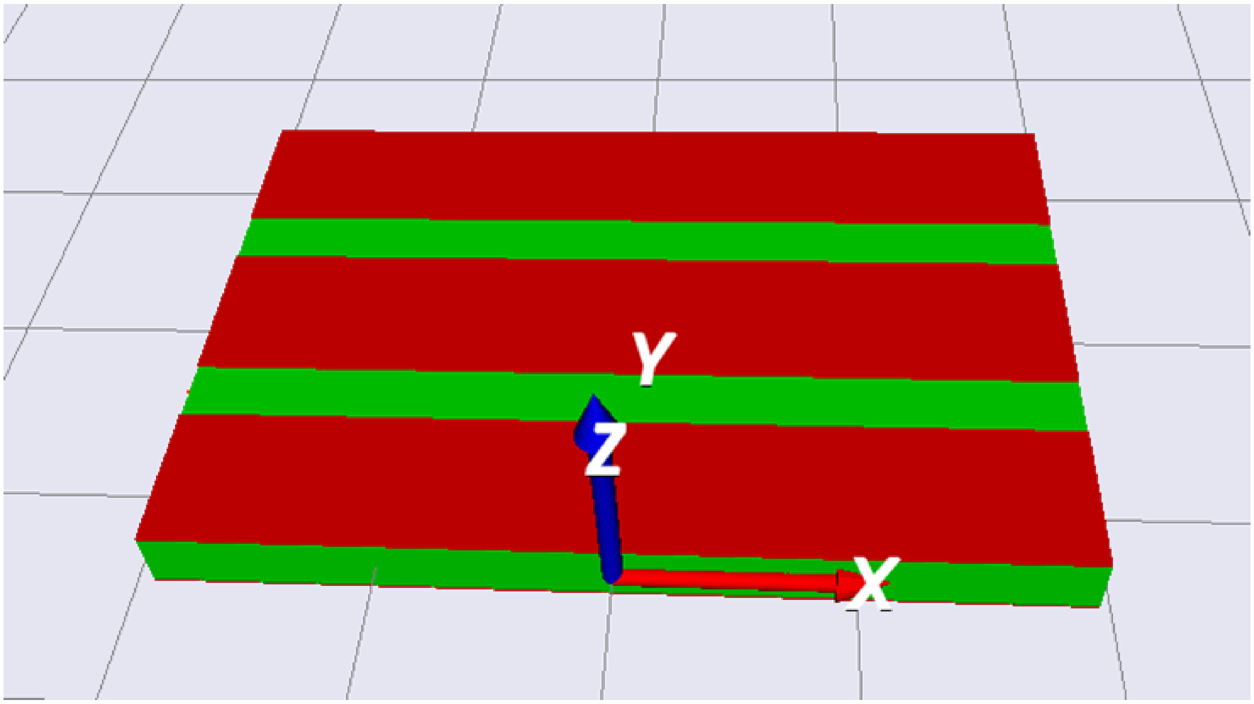
The next step is to model the second ground plane on top of the substrate. Therefore, you should again do the same process. For the dimensions of first ground plane over substrate, you should design the coplanar waveguide. The transversal coordinates can thus be described by X1 = -4.36 Y1 = 4.338, Z1= 0.319 for the first corner and give the actual length as length X = 8.72, length Y = 1.5, length Z = .035 as you did above. You should now assign a meaningful name to the brick by entering e.g. patch 2 in the *Name* field.



Again we have to model the ground plane below the substrate. Therefore, the transversal coordinates can thus be described by X1 = -4.36 Y1 = 0.0, Z1= -0.319 for the first corner and give the actual length as length X = 8.72, length Y = 5.838, length Z = .035 as you did above. You should now assign a meaningful name to the brick by entering e.g. ground plane in the *Name* field.

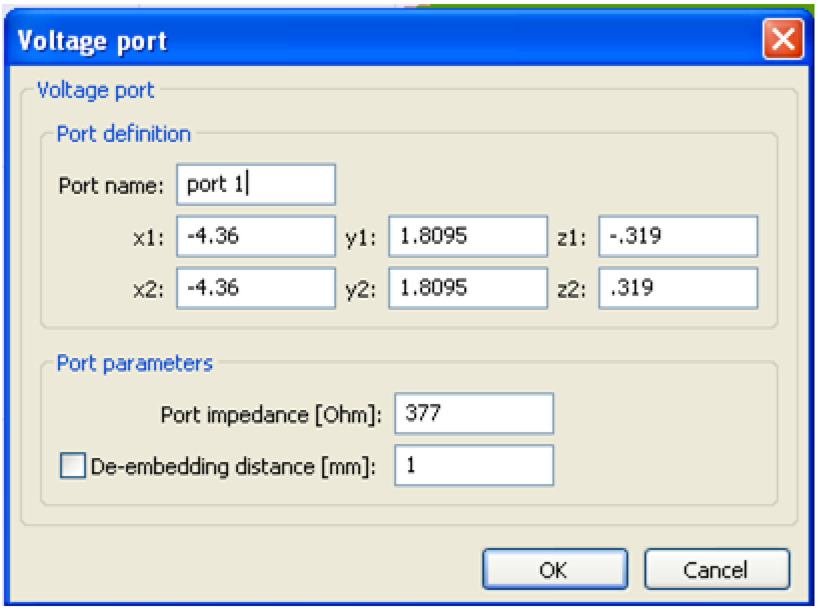


The *Material* setting of the brick must be changed to the desired coplanar material. Because no material has yet been defined for the coplanar waveguide, you should select the PEC as the material for patch 3 and ground plane from the material drop down list and in the brick creation dialog box you can also press the *OK* button to finally create the first ground plane. Your screen should now look as follows

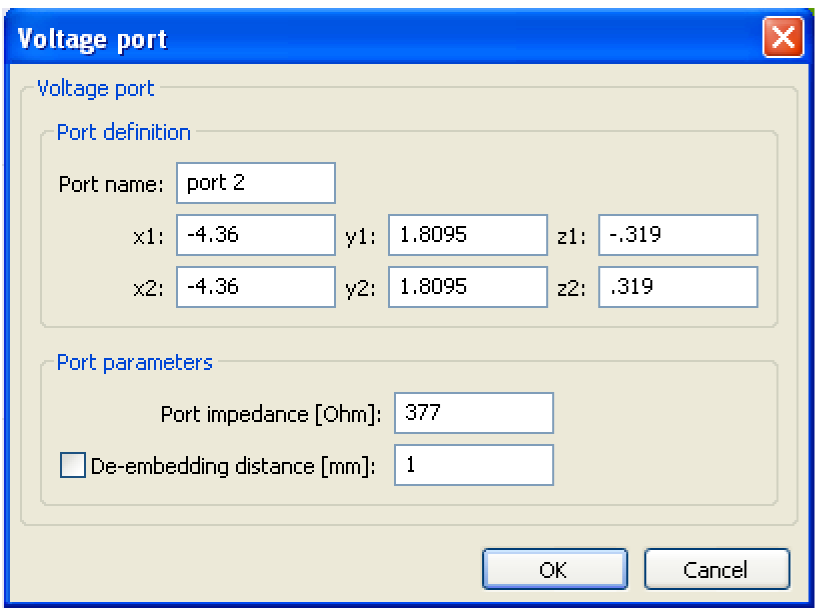


Define Ports

The next step is to add the ports to the coplanar waveguide device for which the S-parameters will later be calculated. Each port will simulate microstripline structure that is connected to the structure at the ports plane. Voltage ports are the most accurate way to calculate the S-parameters of coplanar devices and should thus be used here. For defining port 1 give the port name as port 1 and give all the dimensions for finalizing the port press OK.

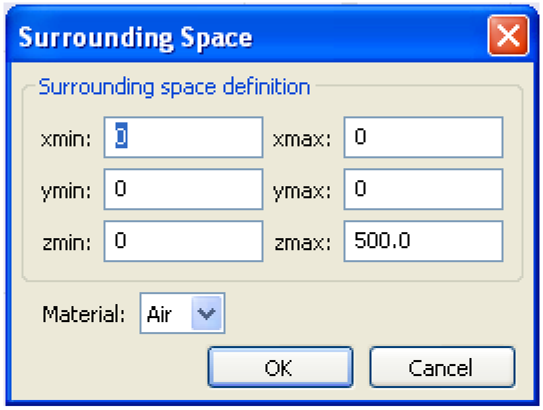


Similarly for defining port 2 give the port name as port 2 and give all the dimensions for finalizing the port press OK.



Define Surrounding Space:

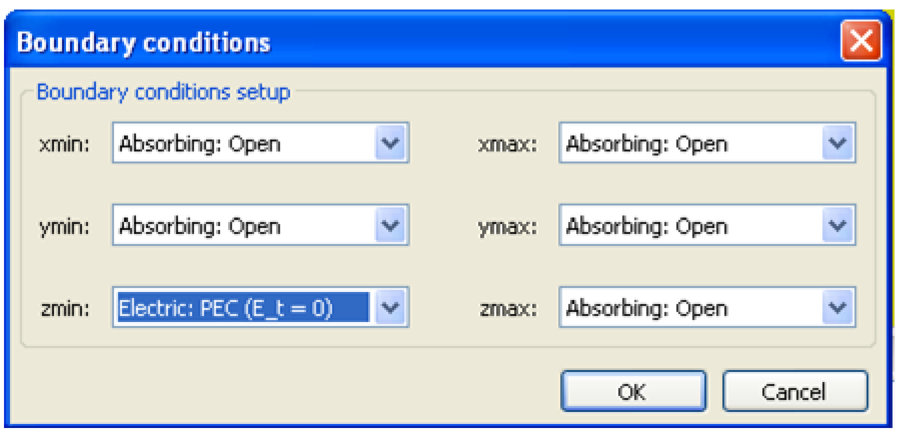
For defining the surrounding space go to simulation and click the surrounding space it will open a dialog box as shown in picture below



Give zmax as 500 and define air as the surrounding material from the material drop down list and press ok for finalizing the condition.

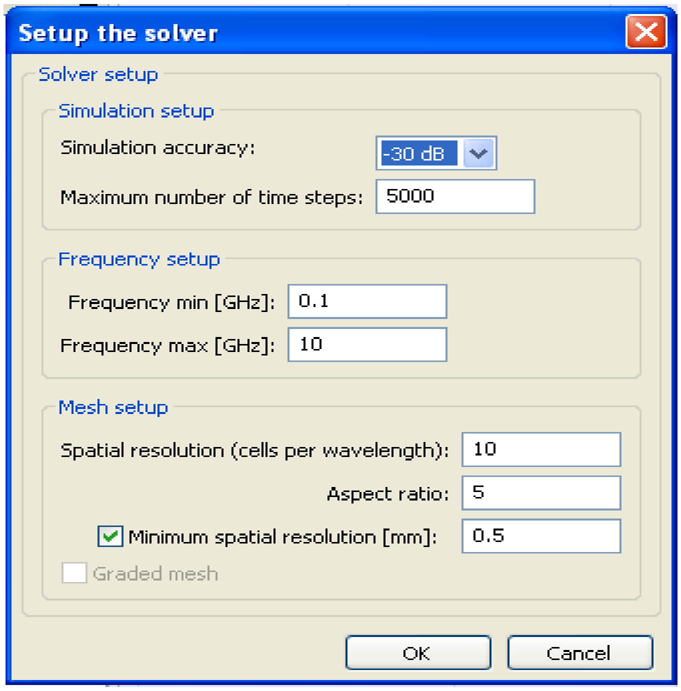
Define the Boundary Conditions

Go to simulation and double click on boundary condition then a boundary condition setup box will open give zmin as Electric: PEC (E_t = 0) and press OK.



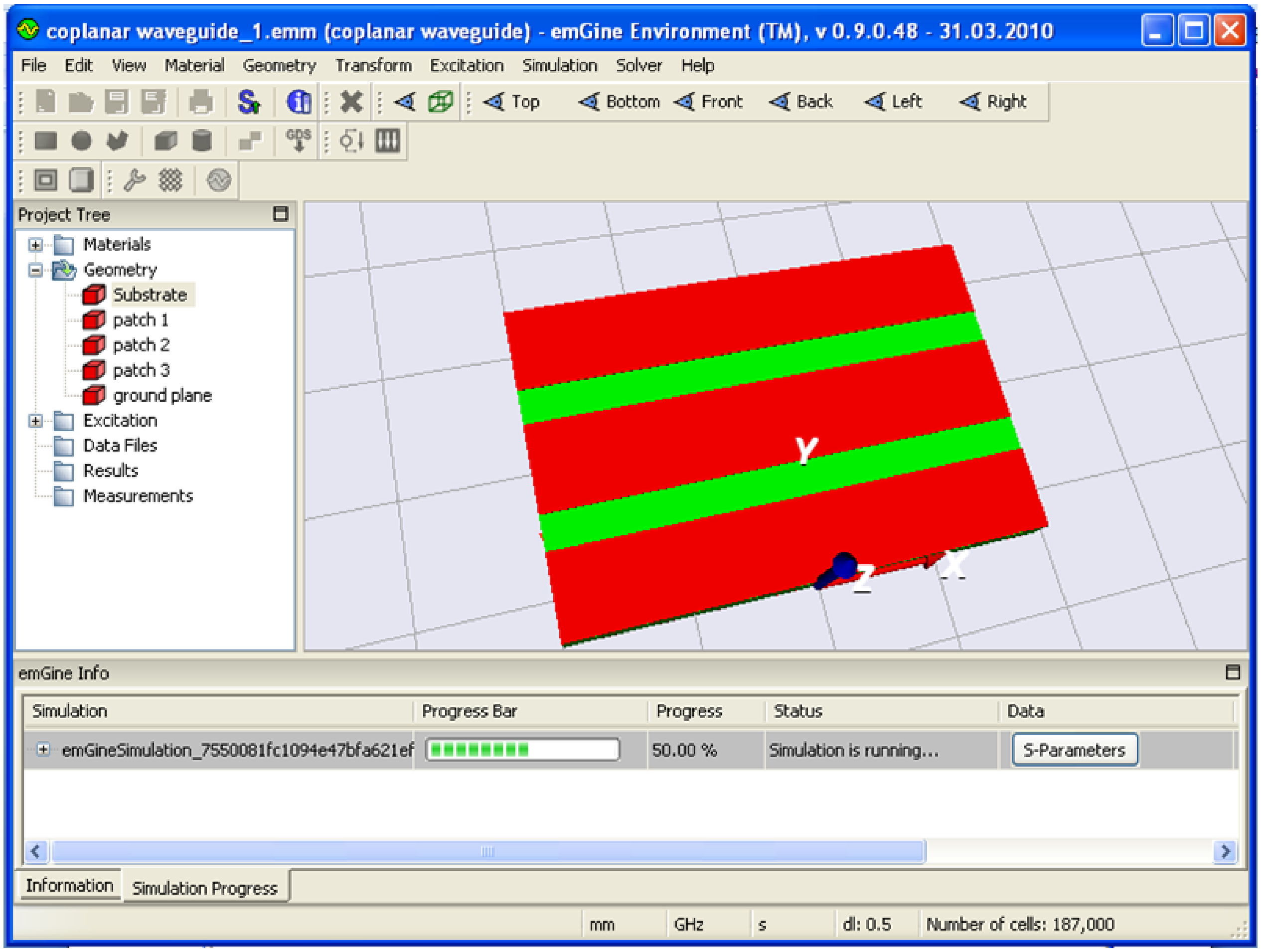
Setup the Solver

The next step is solver setting for this go to solver and by pressing setup a dialog will open. In this box simulation accuracy should be -30dB. You can choose maximum number of the time steps between 500 and 5000. Choose 5000 steps. After that define the frequency range for the simulations you can set frequency min as 0.1 GHz and frequency max as 10 GHz. Hence, your frequency range is from 0.1 GHz to 10 GHz. Now define Special resolution as 10, Aspect ratio as 5 and give minimum spatial resolution (mm) as 0. 5. For finalizing the setup solver press OK.



Simulation

Finally to start the simulations go to solver and press *Simulation* button to start the calculation. A progress bar will appear in the status bar, displaying some information about the solver stages.



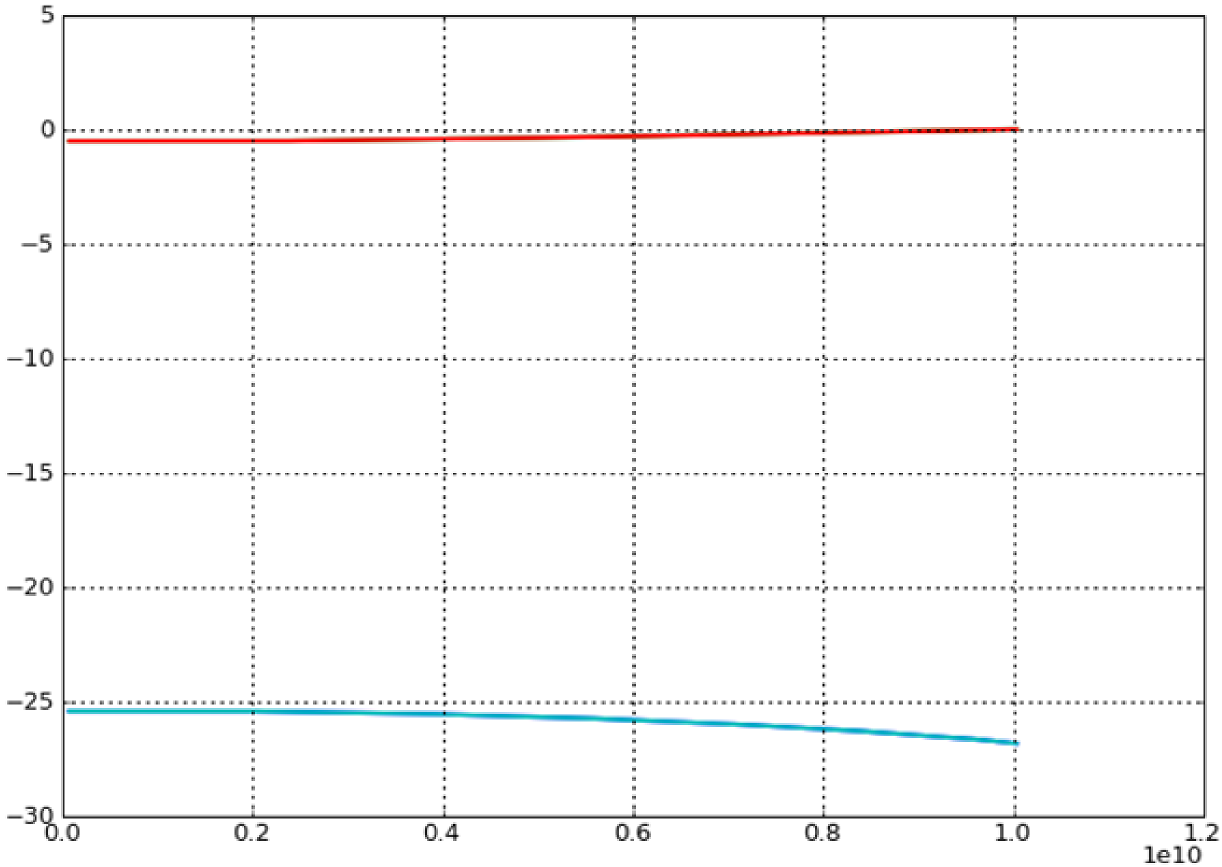
During the simulation, the Message Window will show some details about the performed simulation.

Congratulations, you have simulated the coplanar waveguide! Let's review the results.

Result:

S-Parameters Results

The S-parameters magnitude in dB scale can be plotted by clicking on the *Results: dB* folder



Precautions:

- Follow instructions carefully.
- EMgine software should be properly installed.