DAYALBAGH EDUCATIONAL INSTITUTE,
DAYALBAGH, AGRA

Manual

Experiment 3

Design and Characterization of Slot Line

Experiment 3

Objective:

To design the Slot Line at 3 GHz

1. Calculate the length and width of Slot Line at 3 GHz

To simulate the Slot Line

1. Specify the Slot line 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 slot line structure is a planar structure. It consists of a dielectric substrate, in which a slot is etched on the metallization of the substrate. The other surface is without any metallization. The series and parallel elements can be connected without much difficulty in this type of substrate. The structure is thus complementary to that of the microstrip. The slot-line configuration (shown in Fig. 1) is useful in circuits requiring high-impedance lines, series stubs, and short circuit and in hybrid combinations with microstrip circuit in MICs.

Approximate electric and magnetic field distribution in the structure are shown in fig. 2. It can be seen that the magnetic field has a component in the direction of propagation as well. Thus the mode of propagation is TE mode and not the TEM mode. The main features of slot line are as follows.

1. The slot transmission line has a simple geometry that is compatible with microwave integrated circuits.

2. In a slot line, both the conductors are in one plane, and therefore shunt mounting of the component (active or passive) across the line is very convenient.

3. In the cross section of the line, at some region the magnetic field is circularly polarized. This feature can be used in the design of several ferrite components such as resonance isolators.

4. Slot line configuration is useful in circuits requiring high impedance line, series stub, and short circuit and in hybrid combination with microwave circuits in MICs.

A slotline on a dielectric surface and electric and magnetic field distribution in the slot line are shown in following figure…..

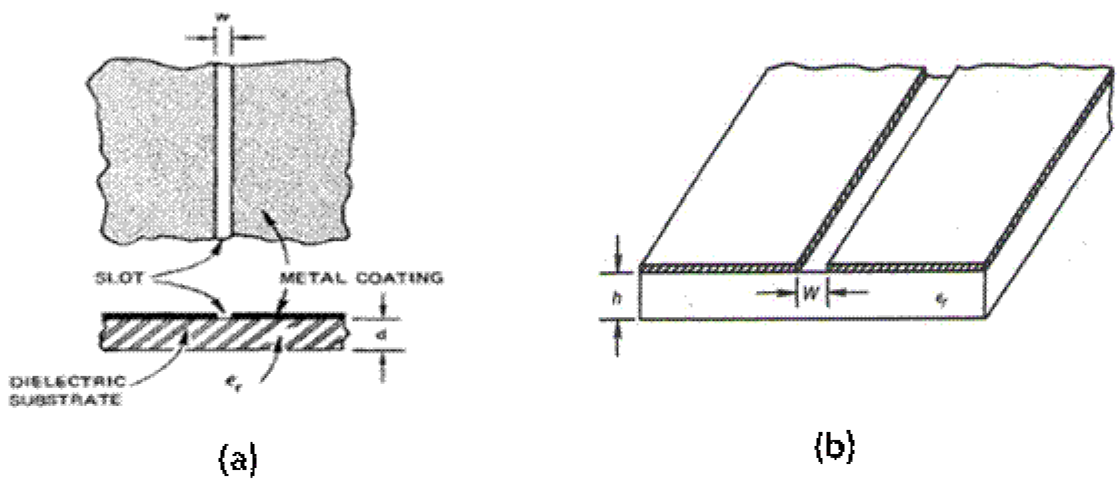


Figure 1: (a) Slot line on a dielectric substrate (b) Slot line configuration

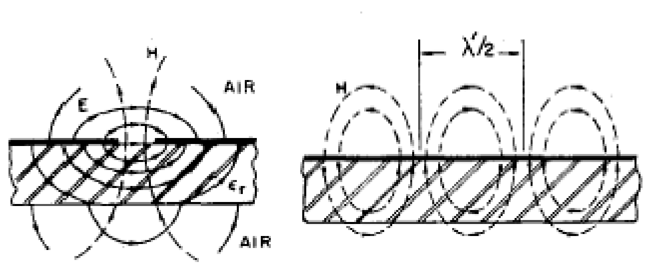


Figure.2 (a) E-field distribution in cross section. (b) H field in longitudinal section

Slot Wavelength: The slot line field component is not confined to the substrate only but extended into the air region above the slot and also below the substrate. Thus the energy is distributed between the substrate and the air region. Therefore, the effective dielectric constant for the slot line is less than the substrate permittivity for an infinitely large thick substrate the average dielectric constant of the two media is:

$$\varepsilon_{r\,e} = \frac{\varepsilon_r + 1}{2}$$

$$\varepsilon_{eff} = \left(\frac{\lambda_g}{\lambda_o}\right)^{-2}$$

This formula is valid for following conditions:

$$9.7 \le \epsilon_r \le 20$$

$$0.02 \le \frac{W}{h} \le 1.0$$

$$0.01 \le \frac{h}{\lambda_0} \le \left(\frac{h}{\lambda_0}\right)_c$$

where $\left(\frac{h}{\lambda_0}\right)_c$ is the cutoff value for the TE_{10} surface-wave mode on the slot line and is given by

$$\left(\frac{h}{\lambda_0}\right)_c = \frac{0.25}{\sqrt{\epsilon_r - 1}}$$

1. For 0.02 $\leq$ W/h $\leq$ 0.2

$$\frac{\lambda_g}{\lambda_0} = 0.923 - 0.195 In \in_r + 0.2\frac{W}{h} - \left(0.126\frac{W}{h} + 0.02\right) In\left(\frac{h}{\lambda_0} \times 10^2\right)$$

$$Z_0 = 72.62 - 15.283 In \in_r + 50\frac{(W/h - 0.02)(W/h - 0.1)}{W/h} + In\left(\frac{W}{h} \times 10^2\right)(19.23 - 3.693 In \in_r)$$

$$- [0.139 In \in_r - 0.11] + \frac{W}{h}(0.465 In \in_r + 1.44) \times \left(11.4 - 2.636 In \in_r - \frac{h}{\lambda_0} \times 10^2\right)^2$$

2. For 0.2 $\leq$ *W/h* $\leq$ 1.0

$$\frac{\lambda_g}{\lambda_0} = 0.987 - 0.21 In \in_r + \frac{W}{h}(0.111 - 0.0022 \in_r) - \left(0.053 + 0.041\frac{W}{h} - 0.0014 \in_r\right) In\left(\frac{h}{\lambda_0} + 10^2\right)$$

$$\begin{aligned} Z_o = 113.19 - 23.257 \ln \varepsilon_r + 1.25\frac{W}{h}(114.59 - 22.531 ln\varepsilon_r) + 20\left(\frac{W}{h} - 0.2\right)\left(1 - \frac{W}{h}\right) \\ - \left[0.15 + 0.1\, ln\varepsilon_r + \frac{W}{h}(-0.79 + 0.899 ln\varepsilon_r)\right] \\ \times \left[10.25 - 2.171 ln\varepsilon_r + \frac{W}{h}(2.1 - 0.617 ln\varepsilon_r) - \frac{h}{\lambda_o} \times 10^2\right]^2 \end{aligned}$$

Formula Used:

To design the slot line, we have to calculate the guided wavelength which is equal to length of the slot line.

Procedure is given as following:

To calculate the the guided wavelength of the slotline (equal to length of slot line) first of all we have to calculate the value of wavelength λ_0 corresponding to given frequency at which we want to design slot line.

$$\lambda_0 = \frac{c}{f}$$

Where

λ_0= wavelength in free space

c = velocity of light in free space

Conditions are given as following

$$9.7 \leq \epsilon_r \leq 20$$

$$0.02 \leq \frac{W}{h} \leq 1.0$$

$$0.01 \leq \frac{h}{\lambda_0} \leq \left(\frac{h}{\lambda_0}\right)_c$$

where $\left(\frac{h}{\lambda_0}\right)_c$ is the cutoff value for the TE_{10} surface-wave mode on the slot line and is given by

$$\left(\frac{h}{\lambda_0}\right)_c = \frac{0.25}{\sqrt{\epsilon_r - 1}}$$

Calculate the ratio $\frac{\lambda_g}{\lambda_0}$ for given case

Case 1: For 0.02 $\leq$ W/h $\leq$ 0.2

$$\frac{\lambda_g}{\lambda_0} = 0.923 - 0.195 \ln \epsilon_r + 0.2 \frac{W}{h} - \left(0.126 \frac{W}{h} + 0.02\right) \ln\left(\frac{h}{\lambda_0} \times 10^2\right)$$

Case 2: . For 0.2 $\leq$ *W/h* $\leq$ 1.0

$$\frac{\lambda_g}{\lambda_0} = 0.987 - .21 \ln \epsilon_r + \frac{W}{h} (0.111 - 0.0022\, \epsilon_r) - \left(0.053 + 0.041 \frac{W}{h} - 0.0014\epsilon_r\right) \ln \left(\frac{h}{\lambda_0} + 10^2\right)$$

Example: Calculate the wavelength (length) of slot line at 2.67 GHz .

Given Parameters:

Frequency f = 2.67 GHz

Substrate Thickness h = 3.4798 mm

Width of slot line W = 0.635 mm

Substrate Permittivity ε_r = 20

Characteristic Impedance z_0 = 50 Ω

Speed of light c = 3×10^8

Calculate the wavelength λ_0

$$\lambda_0 = \frac{c}{f}$$

$$\lambda_0 = \frac{3 \times 10^8}{2.67 \times 10^9}$$

$$\lambda_0 = 0.1123\, m$$

Now calculate the value of

$$\left(\frac{h}{\lambda_0}\right)_c = \frac{0.25}{\sqrt{\epsilon_r - 1}}$$

$$\left(\frac{h}{\lambda_0}\right)_c = \frac{0.25}{\sqrt{20-1}}$$

$$\left(\frac{h}{\lambda_0}\right)_c = 0.0573$$

Now width W and substrate thickness h are already given so check the case 1

Case 1: For $0.02 \leq W/h \leq 0.2$

W/h = 0.1824

It is clear from the above value that case 1 exist for the calculation of $\frac{\lambda_g}{\lambda_0}$

$$\frac{\lambda_g}{\lambda_0} = 0.923 - 0.195 \ln \epsilon_r + 0.2\frac{W}{h} - \left(0.126\frac{W}{h} + 0.02\right)\ln\left(\frac{h}{\lambda_0} \times 10^2\right)$$

$$\frac{\lambda_g}{\lambda_0} = 0.923 - 0.195 \ln 20 + 0.2\frac{0.635}{3.4798} - \left(0.126\frac{0.635}{3.4798} + 0.02\right)\ln(0.0573 \times 10^2)$$

$$\frac{\lambda_g}{\lambda_0} = 0.3003$$

$$\lambda_g = 0.3003\lambda_0$$

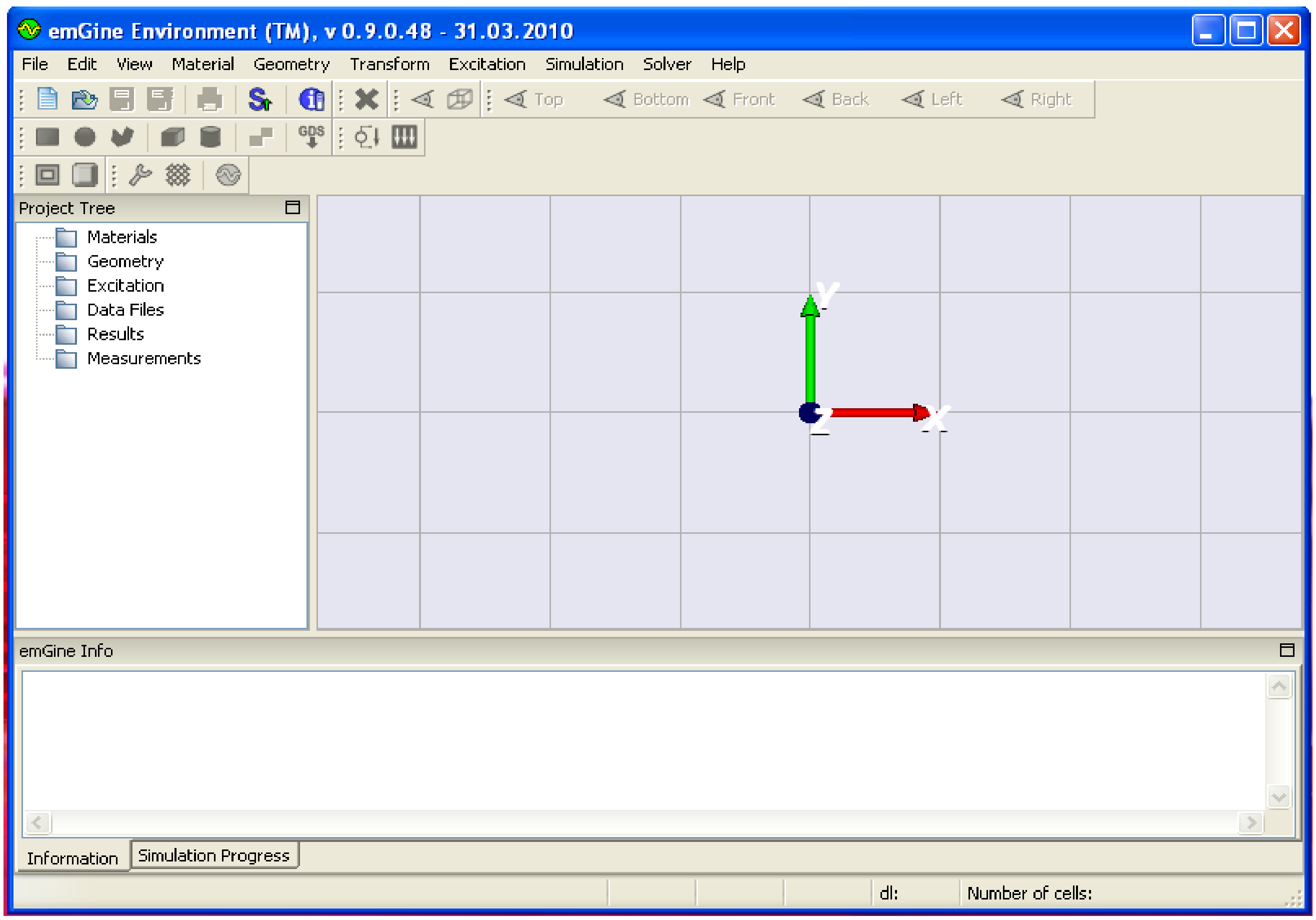
$$\boldsymbol{\lambda_g = 0.03372\ m\ \ 0r\ 33.72\ mm}$$

But we consider case 1 hence guided wavelength of slot line is 33.72 mm. that means the length of slot line is 33.72 mm.

Simulation Procedure:

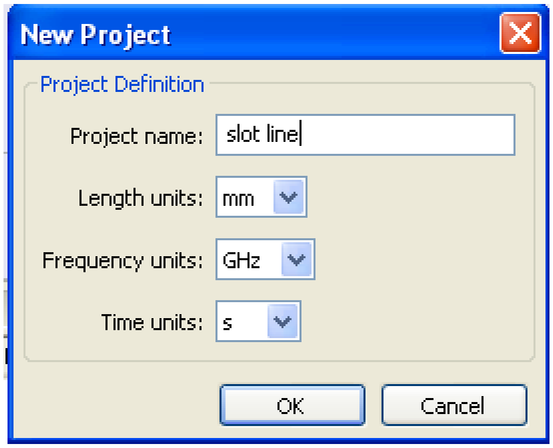
Introduction and Model Dimensions

In this tutorial you will learn how to simulate planar devices. As a typical example for a planar device, you will analyze a Slot Line. 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.

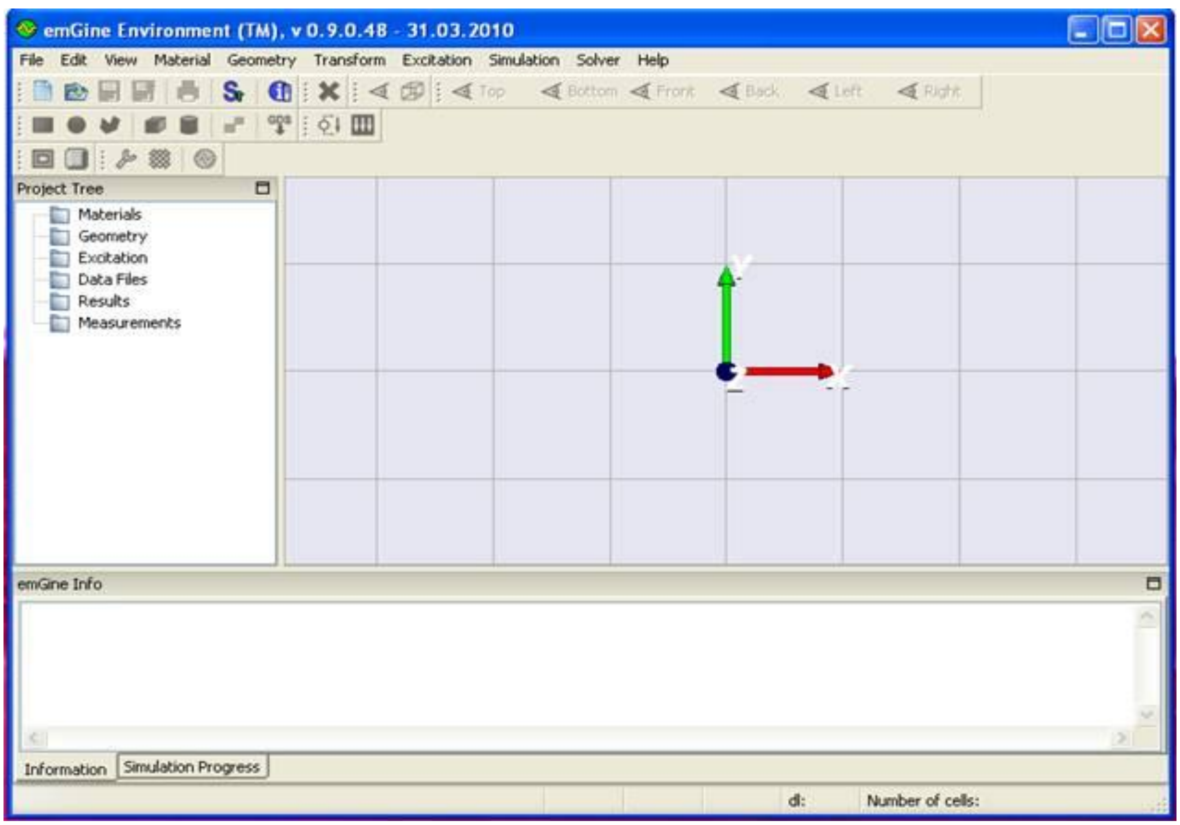


Select a Template

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.



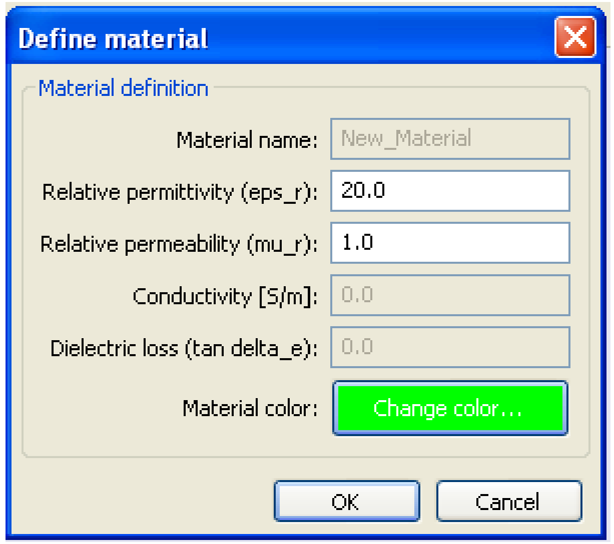
Now again go to file click on save project and save your project at any location in my computer.



Set the Working Planes Properties

The next step is usually to set the material properties. In this dialog box you should define a new *Material name* (e.g. New_Mtarial). Afterwards, specify the material properties in the *Epsilon* and

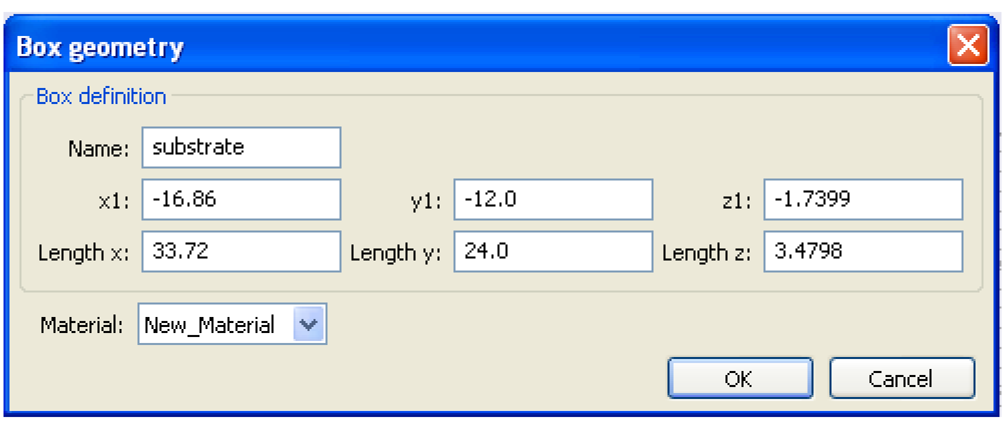
Mue fields. Here, you only need to change the dielectric constant *Epsilon* to 20. Finally, choose a color for the material by pressing the *Change* color button. Your dialog box should now look similar to the picture below before you press the *OK* button.



Draw the Substrate Brick

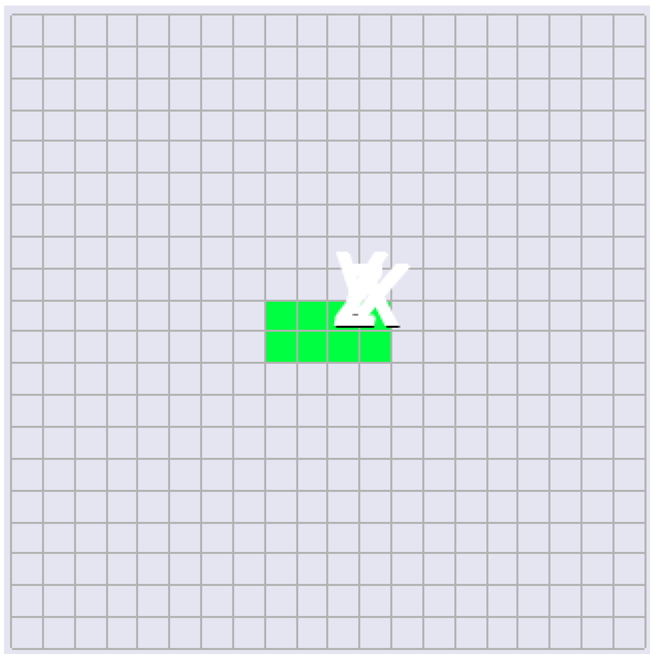
The first construction step for modeling a planar structure is usually to define the substrate layer. This can be easily achieved by creating a brick made of the substrates material. Please activate the brick creation mode (*Geometry - Box*).

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:



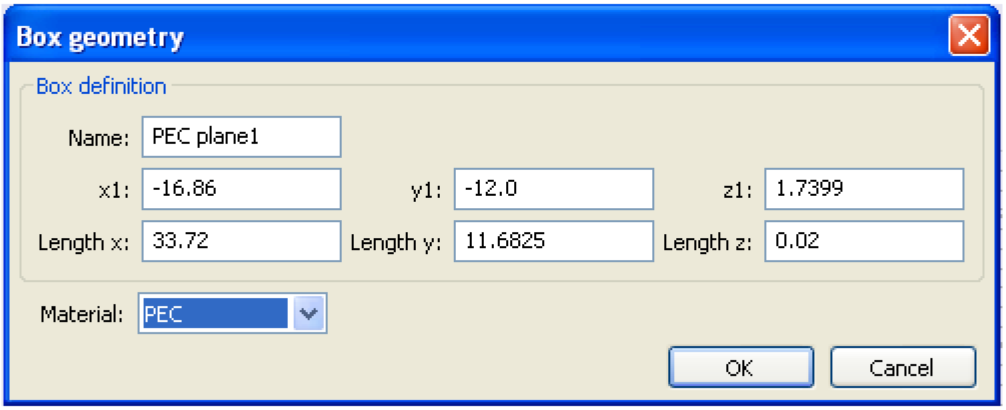
In this example, you should enter a substrate block. The transversal coordinates can thus be described by X 1= -16.86, Y1 = - 12, Z1 = -1.7399 for the first corner and give the calculated length X = 33.72, Y = 24, Z = 3.4798 for creating the brick, assuming that the brick is modeled symmetrically to 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 New_Material 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.

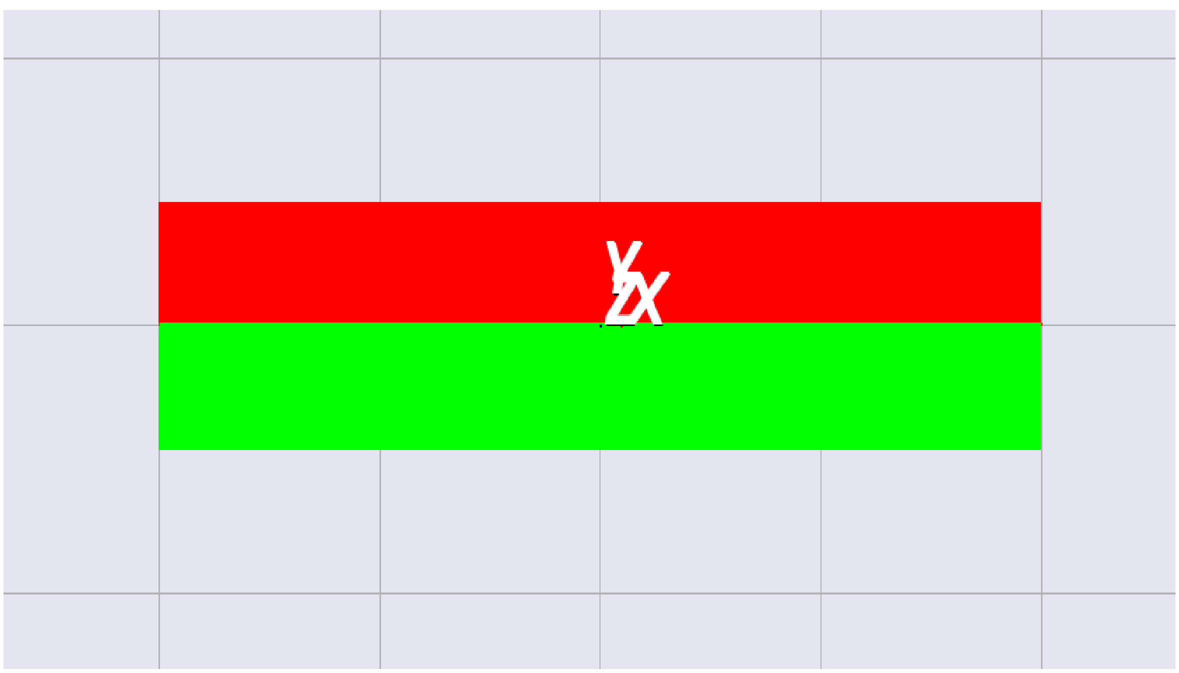


Model the Slot Line

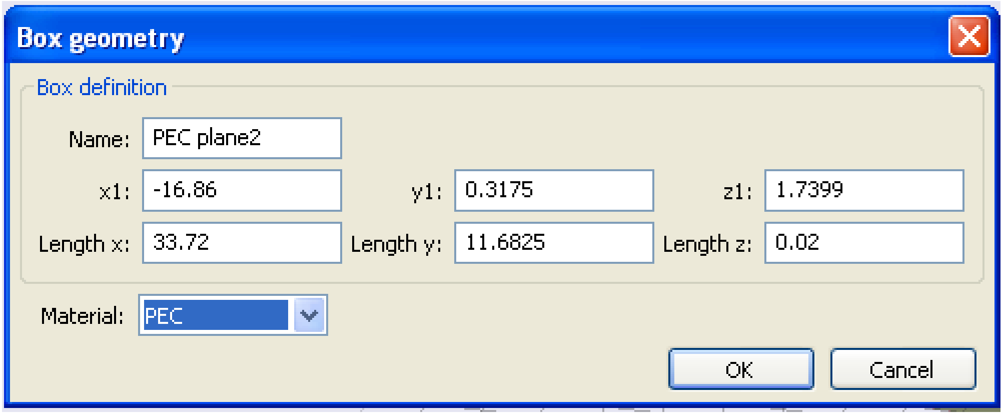
The next step is to model the Slot Line. Therefore, you should design copper plane of PEC material on the top of the substrate. For the dimensions of first PEC plane 1, the transversal coordinates can thus be described by X 1= -16.86, Y1 = -12, Z1 = 1.7399 for the first corner and give the calculated length X = 33.72, length Y = 11.6825, length Z = 0.02. You should now assign a meaningful name to the brick by entering e.g. PEC plane1 in the *Name* field.



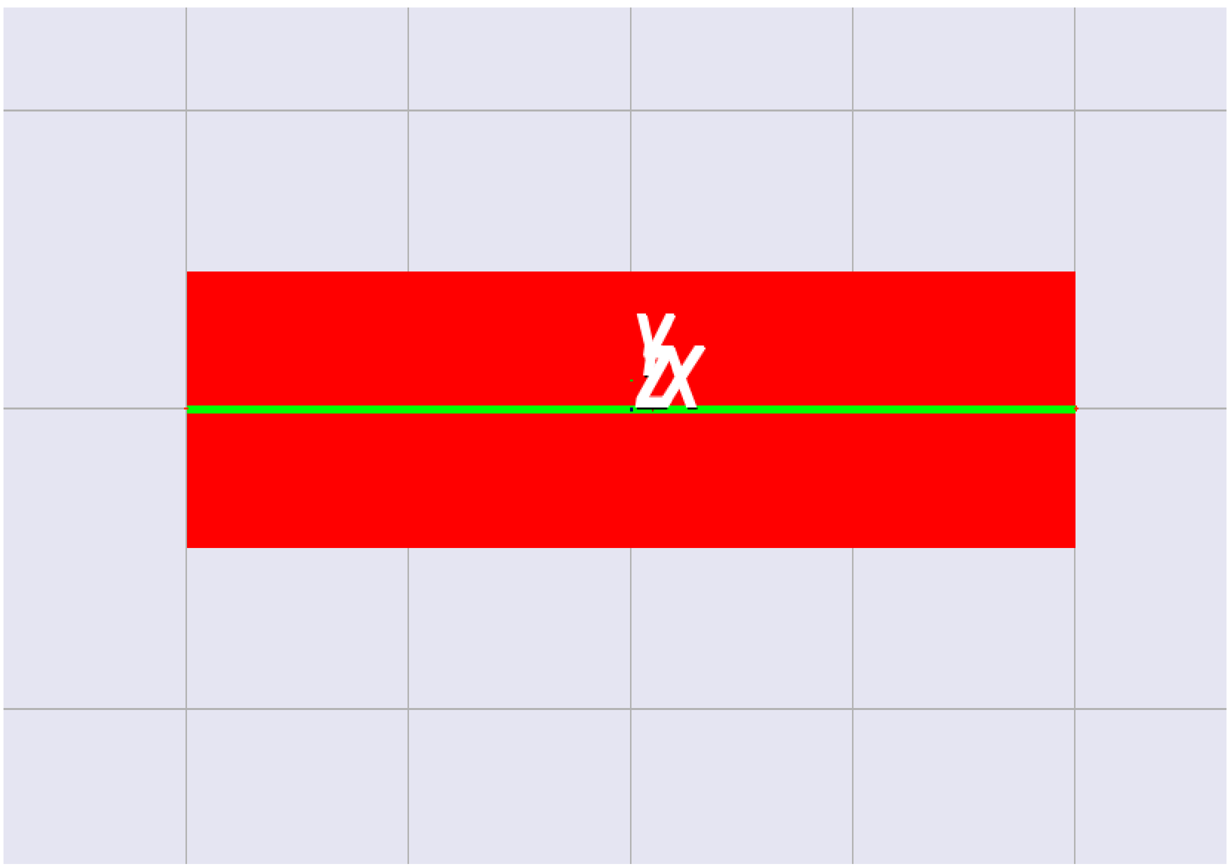
You should select the PEC as the material for PEC plane1 from the material drop down list and in the brick creation dialog box you can also press the *OK* button to finally create the PEC plane 1. Your screen should now look as follows



Again do the same process for creating PEC plane 2. For this purpose again go to geometry select box and in the dialog box give the transversal coordinates can thus as X 1= -16.86, Y1 = 0.3175, Z1 = 1.7399 for the first corner and give the calculated length X = 33.72, length Y = 11.6825, length Z = 0.02. Now assign a meaningful name to the brick by entering e.g. PEC plane2 in the *Name* field.

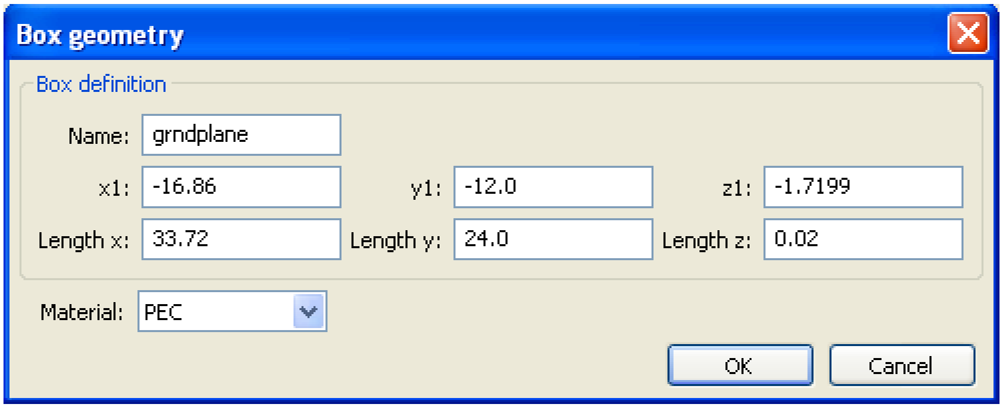


Now select the PEC as the material for PEC plane2 from the material drop down list and in the brick creation dialog box you can also press the *OK* button to finally create the PEC plane 2. Your screen should now look as follows

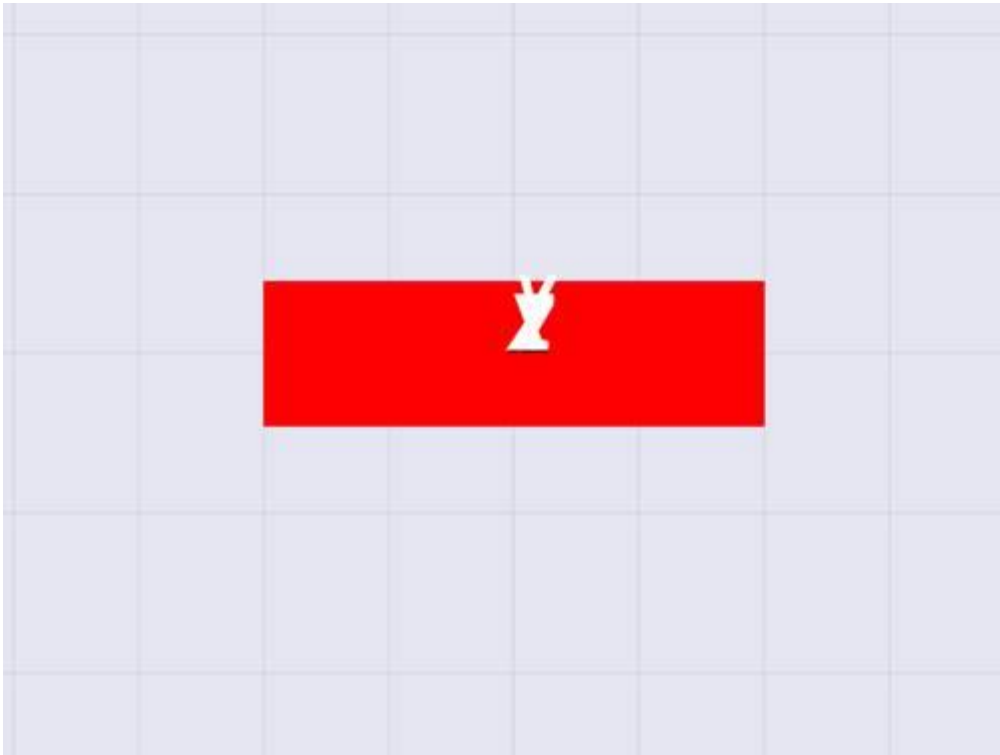


Model the metallic ground plane

The next step is to model the ground plane below substrate. Therefore, you should again do the same process. For the dimensions of ground plane below substrate, you should design the ground plane of PEC patch The transversal coordinates can thus be described by X 1= -16.86, Y1= -12, Z1 = 1.7199 for the first corner and give the calculated length X = 33.72, length Y = 24, length Z = 0.02. You should now assign a meaningful name to the brick by entering e.g. ground plane in the *Name* field.

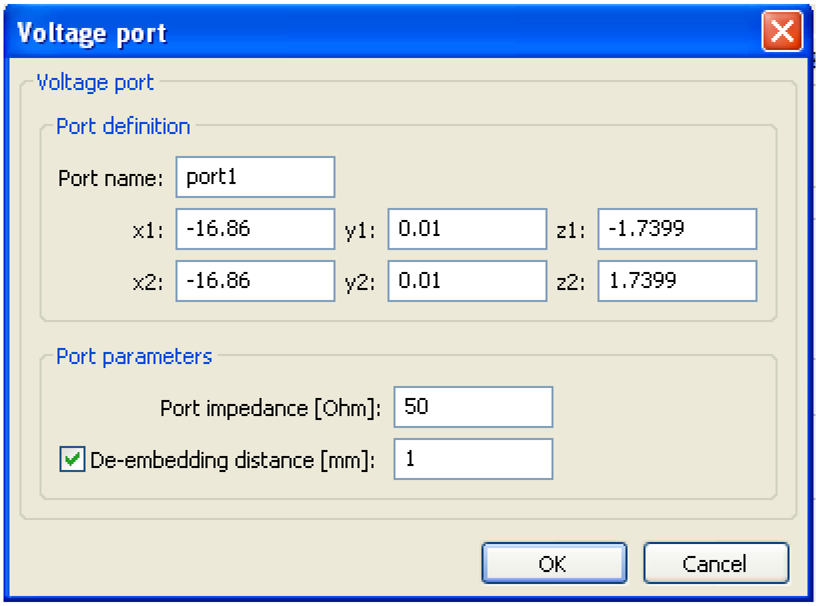


The *Material* setting of the brick must be changed to the desired ground plane. Because no material has yet been defined for the ground plane, you should select PEC as the material for ground plane from the material drop down list and in the brick creation dialog box press the *OK* button to finally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

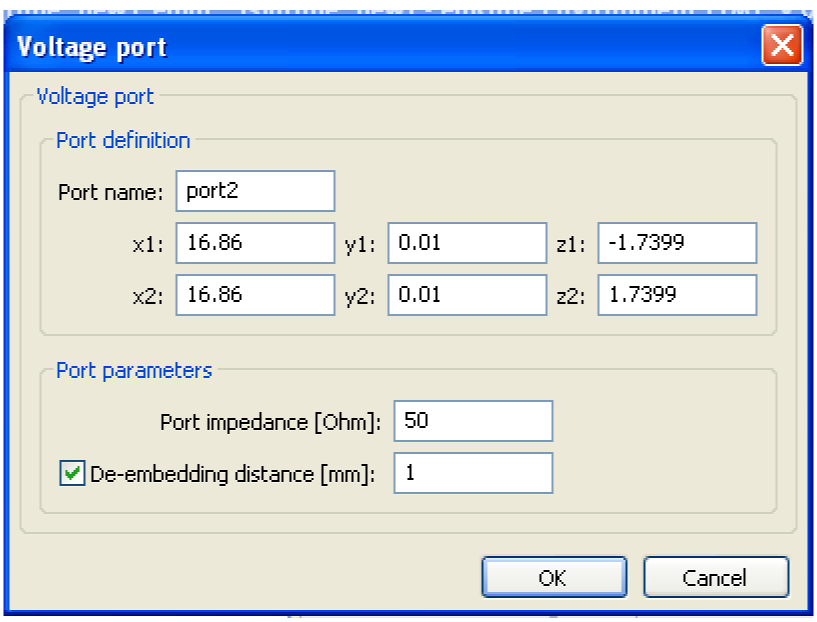


Define Ports

The next step is to add the voltage ports to the slot line device for which the S-parameters will later be calculated. Each port will simulate slot line structure that is connected to the structure at the ports plane. Plane wave ports are the most accurate way to calculate the S-parameters of any microwave device and should thus be used here. To define the port 1 go to excitation and then choose voltage port, it will open a dialog box, give the port name and appropriate dimension to define the exact port. You can define port as shown in picture below.

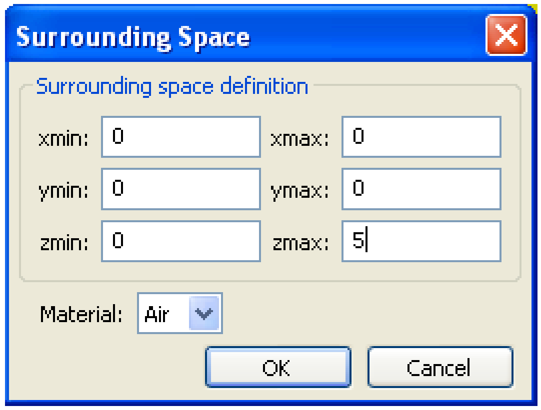


Similarly for defining port 2 give the port name as port 2 and define the coordinates as shown below and then for finalizing the port press ok.



Define Surrounding Space:

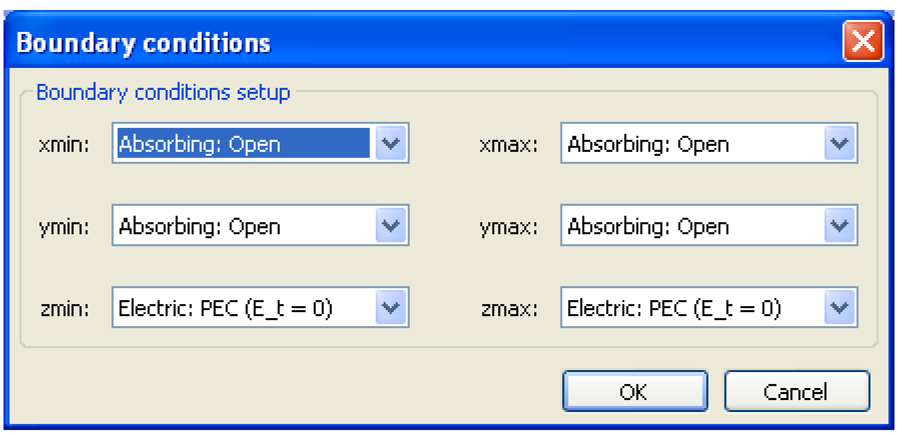
For defining the surrounding space go to simulation and click the surrounding space it will open a dialog box as shown in picture below.



Give zmax as 5 and define air as the surrounding material from the material drop down list and press ok for finalizing the condition.

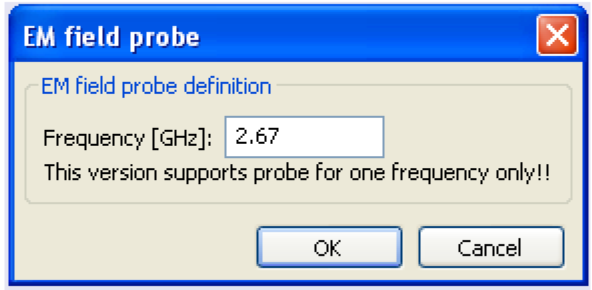
Define the Boundary Conditions

Go to simulation and double click on boundary condition then a boundary condition setup box will open give the boundary conditions according to structure and press ok.



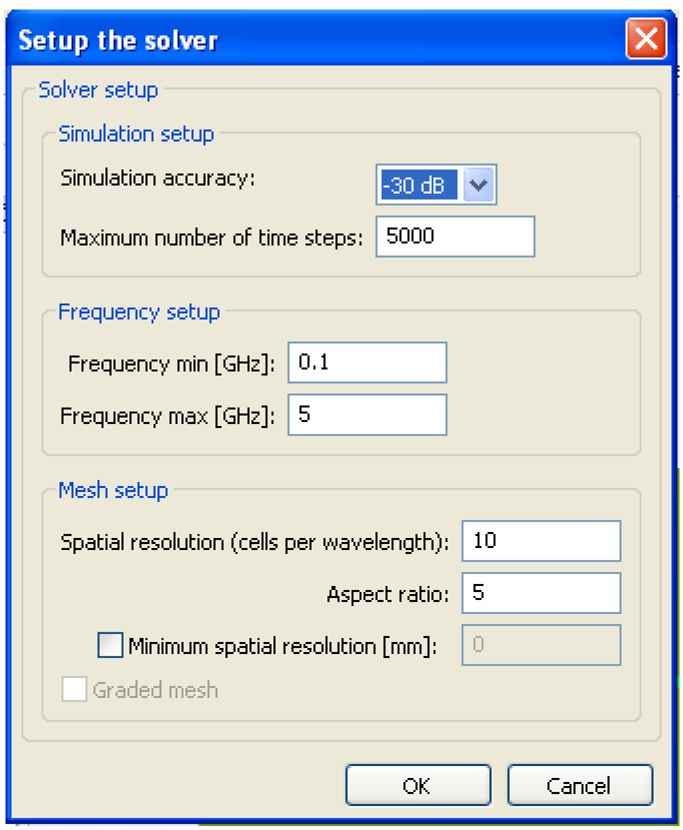
Define the EM Field Visualization

Go to probes and choose EM Field Visualization then an EM Field probe setup box will open Choose 2.67 GHz as frequency and press ok.



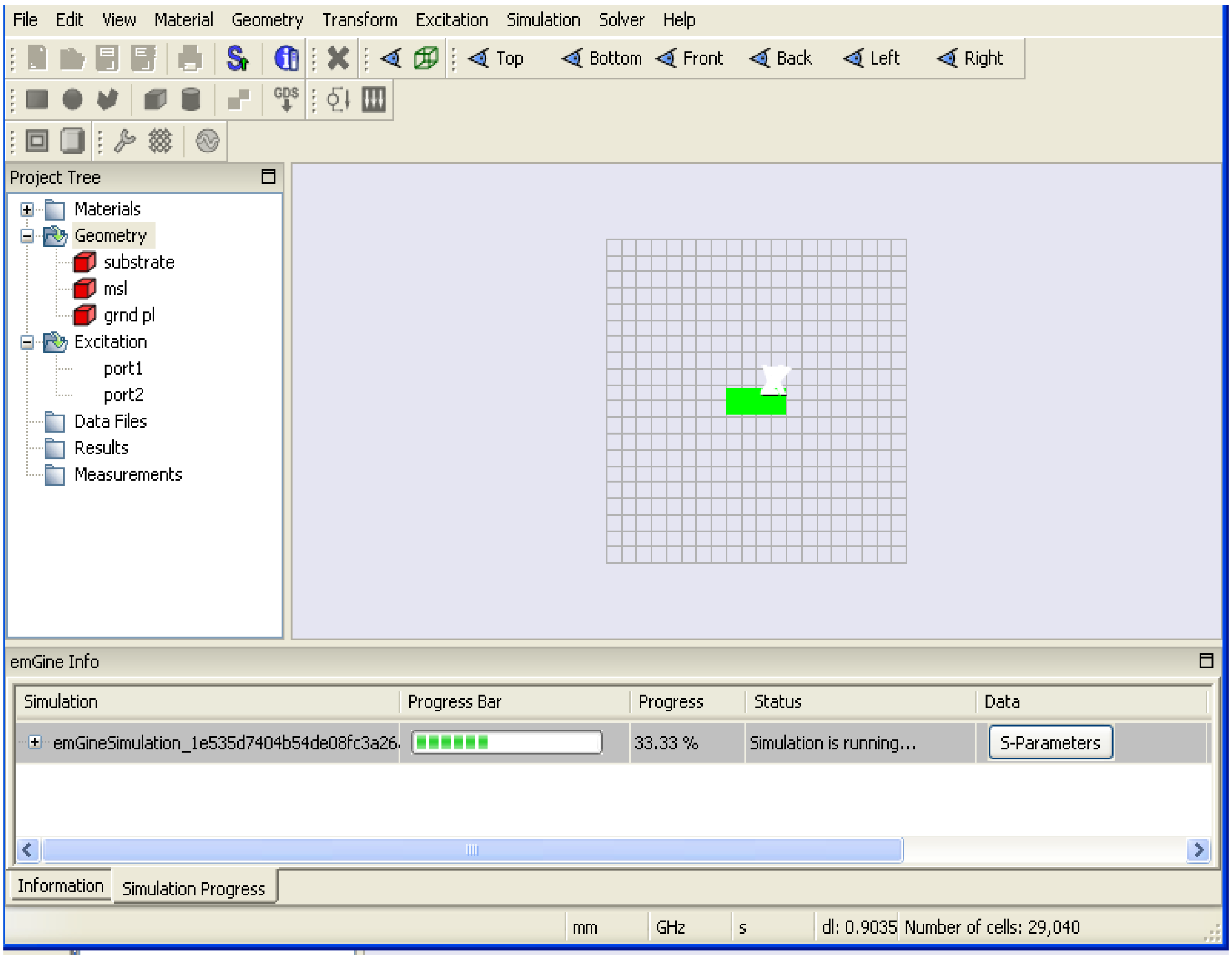
Setup the Solver

The next step is the 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 5 GHz, hence your frequency range is from 0.1 GHz to 5 GHz. Now define Special resolution as 10, Aspect ratio as 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.



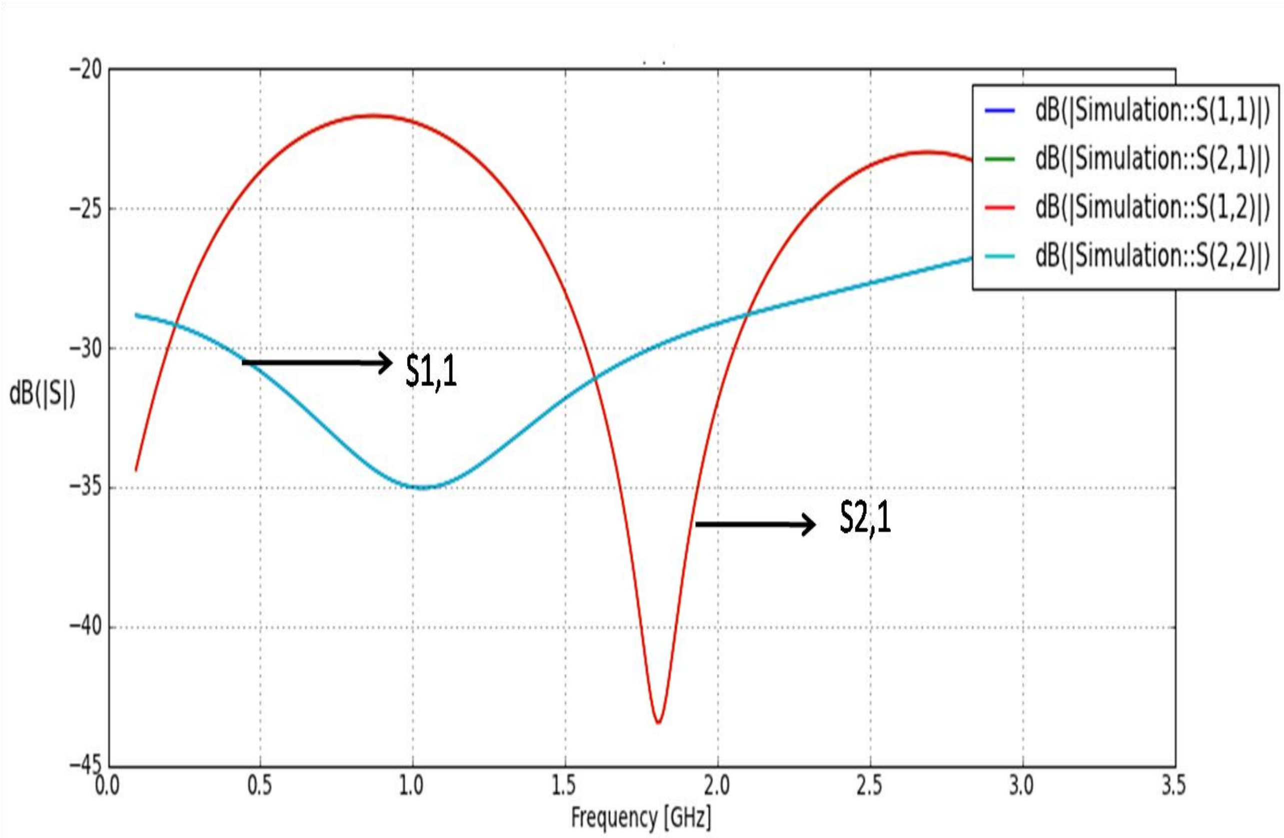
During the simulation, the Message Window will show some details about the performed simulation.

Congratulations, you have simulated the slot line! Let's review the results.

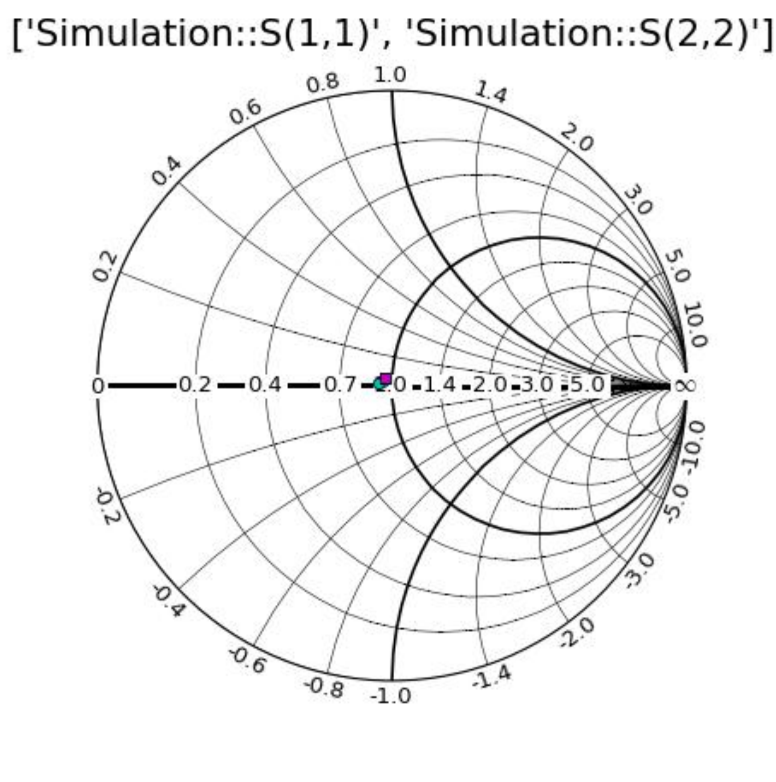
Results:

S-Parameters Results

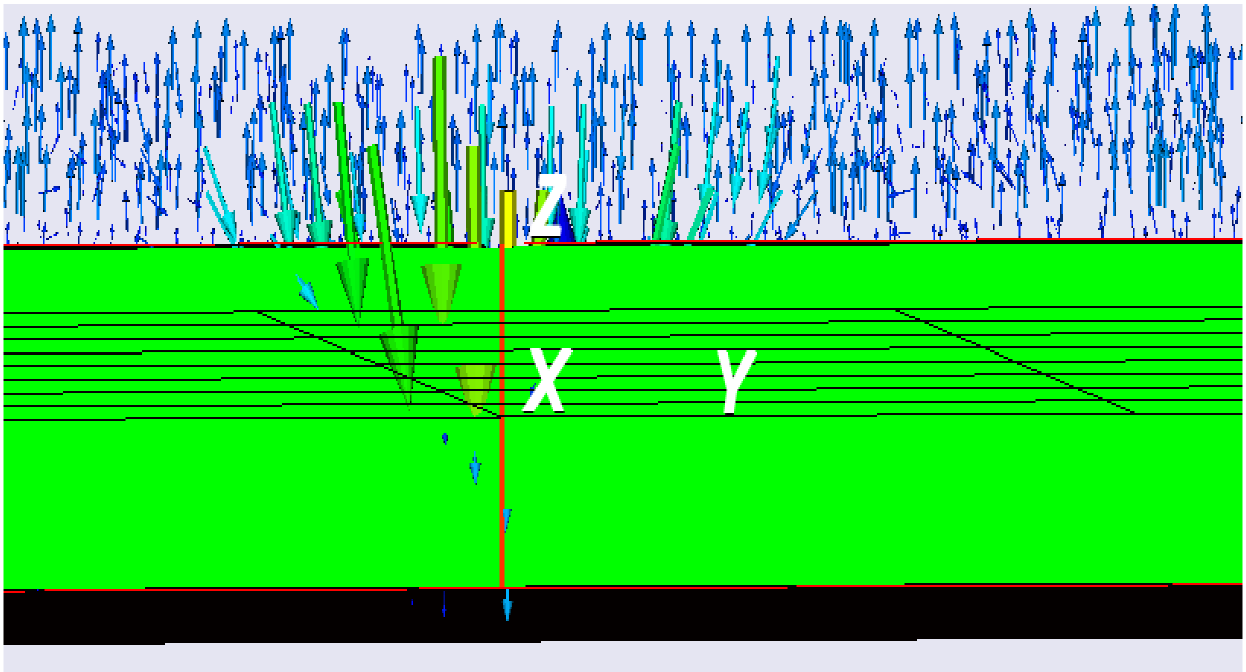
The S-parameters magnitude in dB scale can be plotted by clicking on the *Results: dB* folder.



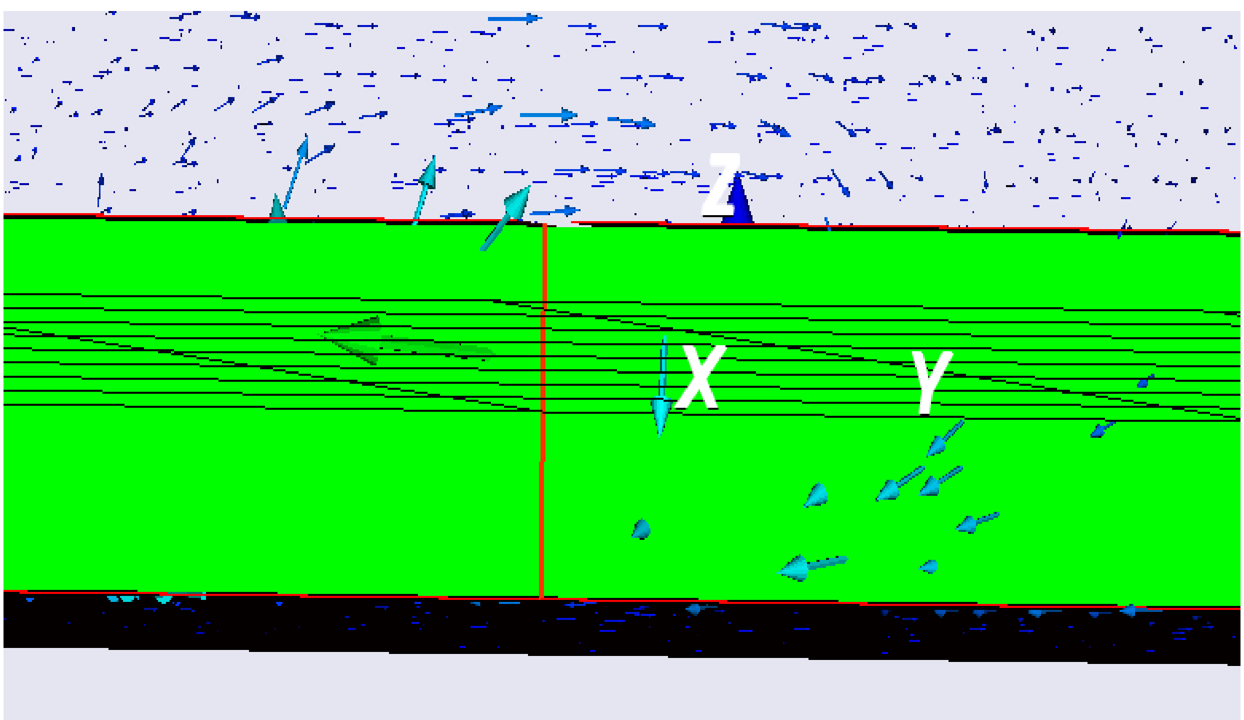
The smith chart can also be seen from Smith chart folder.



The computed electric field – E-field at 2.67 GHz – of the Slot Line



The computed H-field at 2.67 GHz – of the Slot Line.



Precautions:

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