DAYALBAGH EDUCATIONAL INSTITUTE,
DAYALBAGH, AGRA

Manual

Experiment 10

Design and Characterization of Square Resonator

Experiment 10

Objective:

To design the Square Resonator at 1.5 GHz

1. Calculate the length and width of Square Resonator at 1.5 GHz

To simulate the Square Resonator

Specify the Square Resonator parameter

1. Define the geometric modal
2. Define the material data and boundary conditions
3. Run the simulation
4. Analyze the simulation results.

.

Requirement:

1. Computer facility
2. EMgine Simulation Software

Theory:

Square resonator

The square resonator is a transmission line formed in square loop. The basic circuit consists of two feed lines, coupling gap and the resonator. Figure 1 shows the possible circuit arrangement for square resonator. Generally the power is coupled into and out of square resonator through feed lines and the coupling gaps. If the gap between feed lines and the resonator is large then the coupling gap doesn't affect the resonant of the ring. This type of coupling is referred as "loose coupling". When the perimeter of square resonator is equal to an integral multiple of guided wavelength, resonance is established. This may be expressed as

$$4a = n\lambda_g \qquad \text{for } n = 1, 2, 3\ldots\ldots \qquad (1)$$

Where 'a' is side of square, λ_g is guided wavelength and n is the mode number.

Compact size, low cost, and low radiation loss are the desired features of the square resonator. It has been used for the measurement of dispersion, phase velocity, dielectric constant, discontinuities and other special applications. This structure is also used for designing microstrip filters.

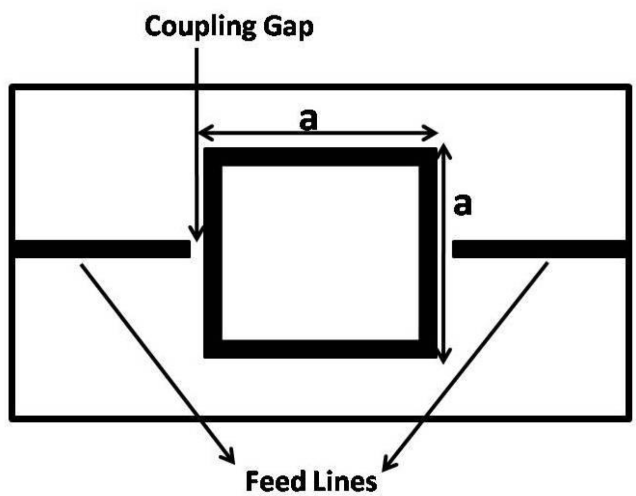


Fig1: Top view of square resonator

Formula Used:

To design Square Resonator, we have to calculate the width and length of the square resonator.

Procedure is given as following:

Width of microstrip line

To calculate the width of the square resonator, we will use following formula.

(Note: calculations of width and guided wavelength of square resonator is same as we did in microstrip line. The only difference is that we consider the length of one side of the square resonator as 1/4 of the guided wavelength because the resonance condition for square resonator is 4a = n λ_g. Width of the square resonator is same as you have already calculated for microstrip line)

$$\frac{W}{d} = \begin{cases} \frac{8e^A}{e^{2A}-2} & for\ W/d < 2 \\ \frac{2}{\pi}\left[B-1-\ln(2B-1)+\frac{\epsilon_r-1}{2\epsilon_r}\left\{\ln(B-1)+0.39-\frac{0.61}{\epsilon_r}\right\}\right] & for\ \frac{W}{d} > 2 \end{cases}$$

Where w= width of square resonator

ε_r = substrate permittivity

d= substrate thickness

and value of A and B is given by following equations

$$A = \frac{Z_0}{60}\sqrt{\frac{\epsilon_r+1}{2}} + \frac{\epsilon_r-1}{\epsilon_r+1}\left(0.23+\frac{0.11}{\epsilon_r}\right)$$

$$B = \frac{377\pi}{2Z_0\sqrt{\epsilon_r}}$$

Using given parameters, we can calculate the ratio W/*d.* Now value of d is given already. After substituting that value, we can get width of square resonator.

Length of Square resonator

Length of square resonator is equal to 1/4 of guided wavelength. Therefore to calculate length of one side of square resonator, first we have to calculate the guided wavelength which is given by following formula

$$\lambda_g = \frac{c}{\sqrt{\varepsilon_{eff}}.f}$$

Where c = speed of light

ε_{eff} = effective permittivity

f= operating frequency

and effective permittivity ϵ_e is given by following formula

$$\varepsilon_{eff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\frac{1}{\sqrt{1+12d/W}}$$

The length of one side of square resonator 'a' is

a = $\lambda_g/4$

Square resonator is designed by considering the resonator plus two feed lines of length $\lambda_g/4$. The resonators have the open ends on both the sides and these open ends called as coupling gaps because these gaps are situated between resonator and feed lines. We can calculate the length of coupling gap by given formula:

$$l_{oe} = 0.412d\left(\frac{\epsilon_{eff}+0.3}{\epsilon_{eff}-0.258}\right)\left(\frac{\frac{W}{d}+0.262}{\frac{W}{d}+0.813}\right)$$

Total Length of the device = 2(length of feed line) + 2(coupling gap) + length of one side of resonator 'a'

Example: Calculate the length and width of square resonator at 1.5 GHz by using following

Given Parameters:

Frequency f = 1.5 GHz

Substrate Thickness d = 1.1 mm

Substrate Permittivity ε_r = 5.5

Characteristic Impedance z_0 = 50 Ω

Solution:

Calculate the value of A

$$A = \frac{Z_0}{60}\sqrt{\frac{\epsilon_r+1}{2}} + \frac{\epsilon_r-1}{\epsilon_r+1}\left(0.23 + \frac{0.11}{\epsilon_r}\right)$$

$$A = \frac{50}{60}\sqrt{\frac{5.5+1}{2}} + \frac{5.5-1}{5.5+1}\left(0.23 + \frac{0.11}{5.5}\right)$$

A = 1.67

Now calculate the value of B

$$B = \frac{377\pi}{2Z_0\sqrt{\epsilon_r}}$$

$$B = \frac{377 \times 3.14}{2\times 50\sqrt{5.5}}$$

B = 5.04

Now calculate the width W

$$\frac{W}{d} = \begin{cases} \frac{8e^{A}}{e^{2A}-2} & for\ W/d < 2 \\ \frac{2}{\pi}\left[B-1-\ln(2B-1)+\frac{\epsilon_r-1}{2\epsilon_r}\left\{\ln(B-1)+0.39-\frac{0.61}{\epsilon_r}\right\}\right] & for\ \frac{W}{d} > 2 \end{cases}$$

$$\frac{W}{d} = \frac{8e^{1.67}}{e^{2\times 1.67}-2}$$

$$W = 1.78\ mm \qquad for\ W/d < 2$$

$$\frac{W}{d} = \frac{2}{3.14}\left[5.04-1-\ln(2\times 5.04-1)+\frac{5.5-1}{2\times 5.5}\left\{\ln(5.04-1)+0.39-\frac{0.61}{5.5}\right\}\right]$$

$$W = 1.77\ mm \qquad for\ for\frac{W}{d} > 2$$

Hence the width of the square resonator is 1.77 mm

Now calculate effective permittivity ϵ_e

$$\varepsilon_{eff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\frac{1}{\sqrt{1+12d/W}}$$

$$\varepsilon_{eff} = \frac{5.5+1}{2} + \frac{5.5-1}{2}\frac{1}{\sqrt{1+12\times 1.1/1.77}}$$

$$\varepsilon_{eff} = 4.023$$

Calculate the value of guided wavelength

$$\lambda_g = \frac{c}{\sqrt{\varepsilon_{eff}}.f}$$

$$\lambda_g = \frac{3 \times 10^8}{\sqrt{4.023} \times 1.5 \times 10^9}$$

$$\lambda_g = 0.0997\ m\ \ or\ 99.7\ mm$$

Since the resonance condition for square resonator is 4a = n∂̃g

Therefore the length of one side of square resonator **a = nλ_g/4 = 24.925mm**

Where n = 1 for fundamental modes

Length of feed line = **λ_g/4 = 24.925mm**

Width of square resonator is **1.77 mm**

Coupling gap =

$$l_{eo} = 0.412d \left(\frac{\varepsilon_{eff} + 0.3}{\varepsilon_{eff} - 0.258}\right)\left(\frac{\frac{W}{d} + 0.262}{\frac{W}{d} + 0.813}\right)$$

$$l_{eo} = 0.412 \times 1.1 \left(\frac{5.5 + 0.3}{5.5 - 0.258}\right)\left(\frac{\frac{1.77}{1.1} + 0.262}{\frac{1.77}{1.1} + 0.813}\right)$$

***l_{oe}*= 0.41mm**

total length is 2 X 24.925 +2 X 0.43 +24.925

$$total\ lenght = 2 \times 24.925 + 2 \times 0.43 + 49.85$$

total length of the device= 75.5716mm

total width of the device = 40mm

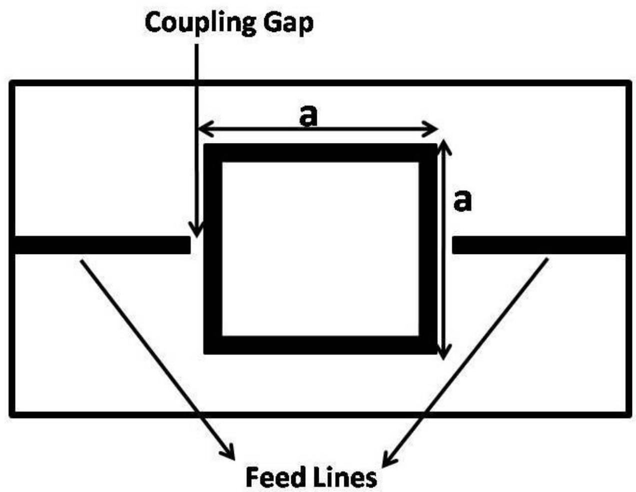


Fig1:Top view of square resonator

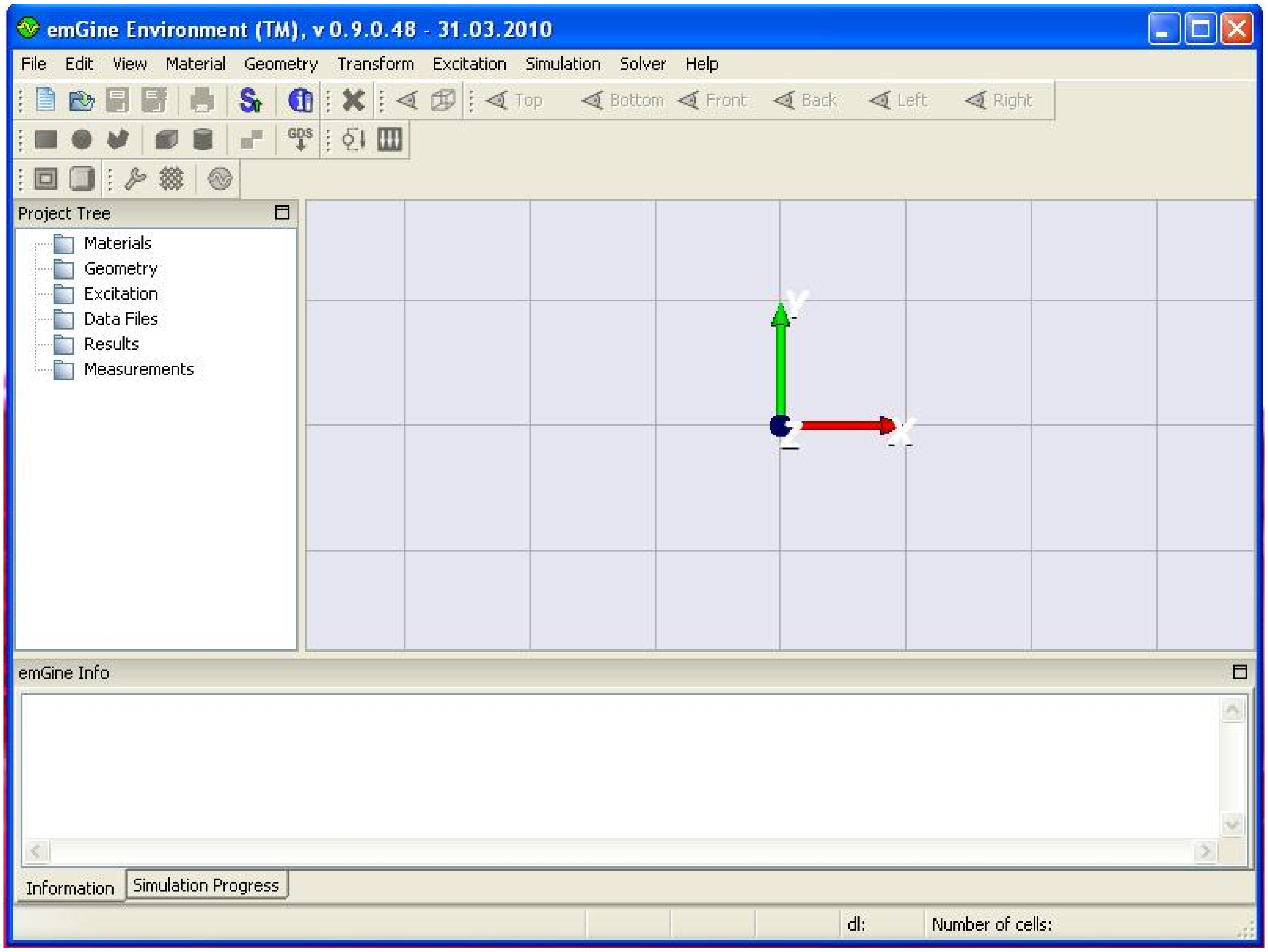
Simulation Procedure:

Introduction and Model Dimensions

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

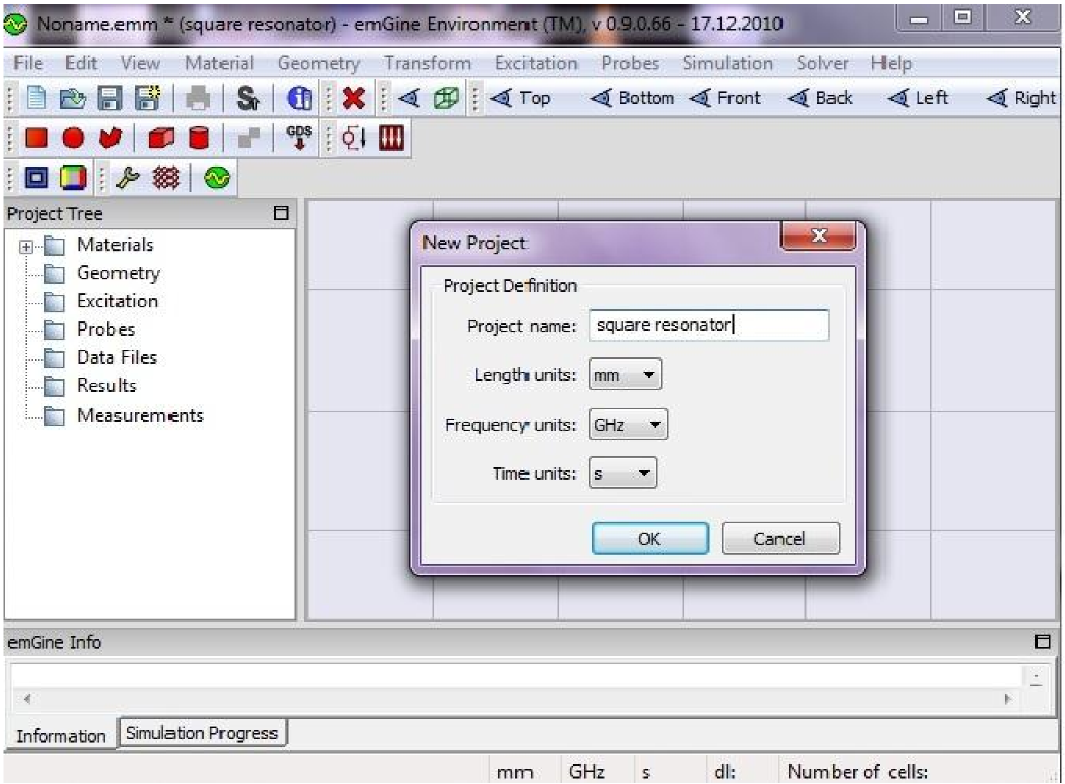
Geometric Construction Steps

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

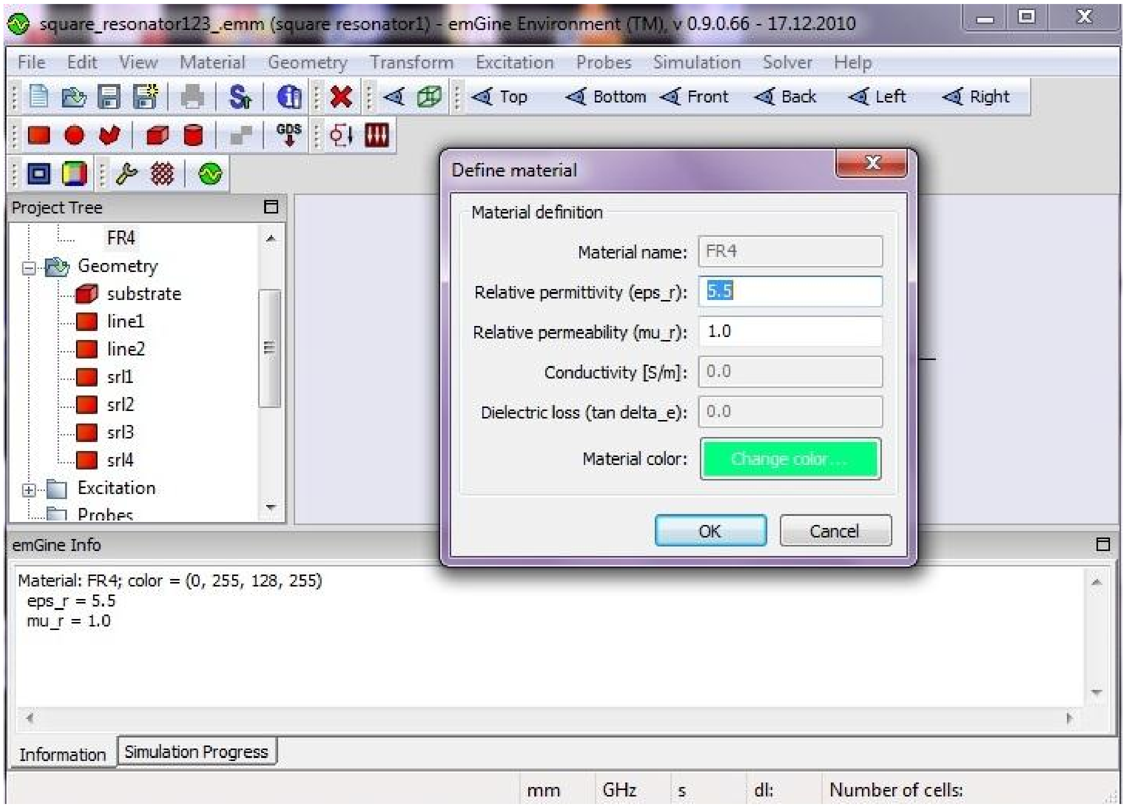
Once you have started emGin, go to file and click on new project a dialog box will open to give the appropriate name for the new project. You should set the units in mm, GHz and s and press ok.



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

Set the Working Planes Properties

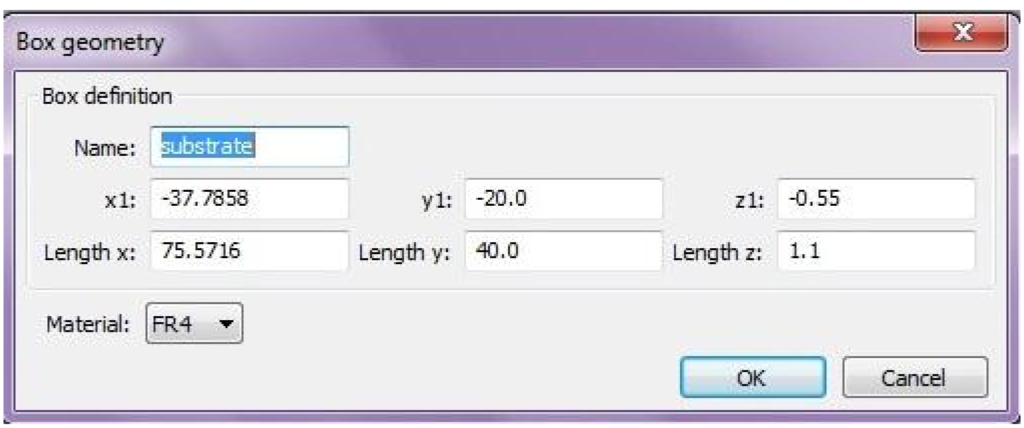
The next step is usually to set the material properties. In this dialog box you should define a new *Material name* (e.g. New_Mtarial). Afterwards, specify the material properties in the *Epsilon* and *Mue* fields. Here, you only need to change the dielectric constant *Epsilon* to 5.5. Finally, choose 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

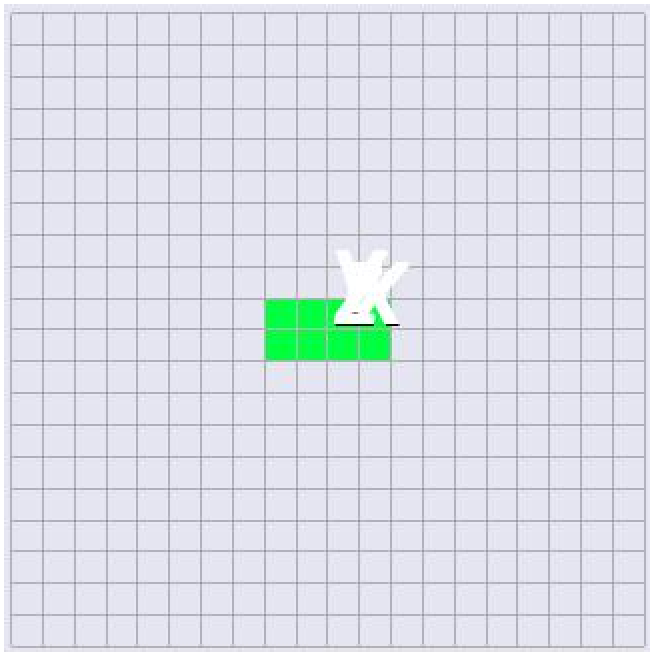
The first construction step for modeling a planar structure is usually to define the substrate layer. This can be easily achieved by creating a brick made of the substrates material. Please activate the brick creation mode (*Geometry - Box*).

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:



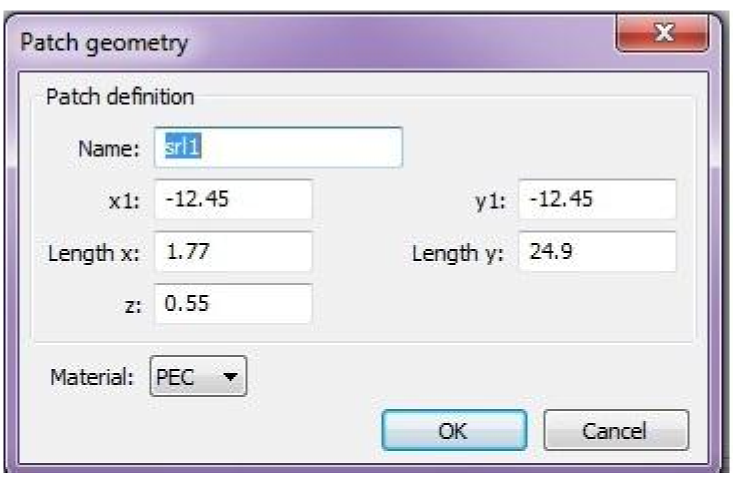
In this example, you should enter a substrate block. The transversal coordinates can thus be described by X 1= -37.7858, Y1 = -20.0, Z1 = -0.55 for the first corner and give the calculated length X = 75.5716, Y = 40, Z = 1.1 for creating the brick, assuming that the brick is modeled symmetrically to 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.

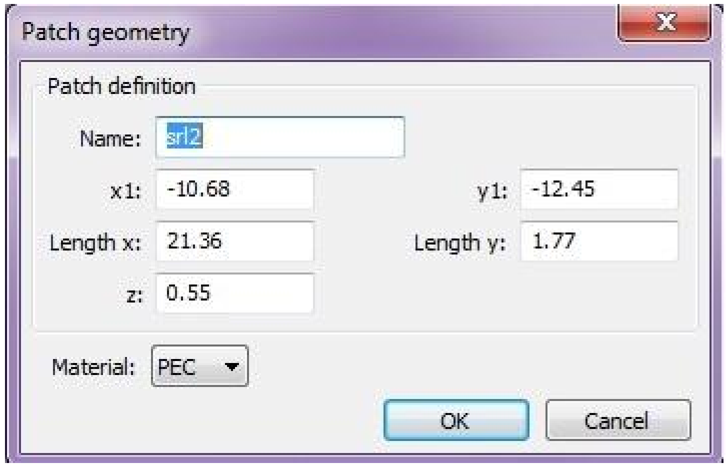
The *Material* setting of the brick must be changed to the desired substrate material. Because no material has yet been defined for the substrate, you should open the layer definition dialog box by selecting New_Material from the *Material* dropdown list. Now in the brick creation dialog box you can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



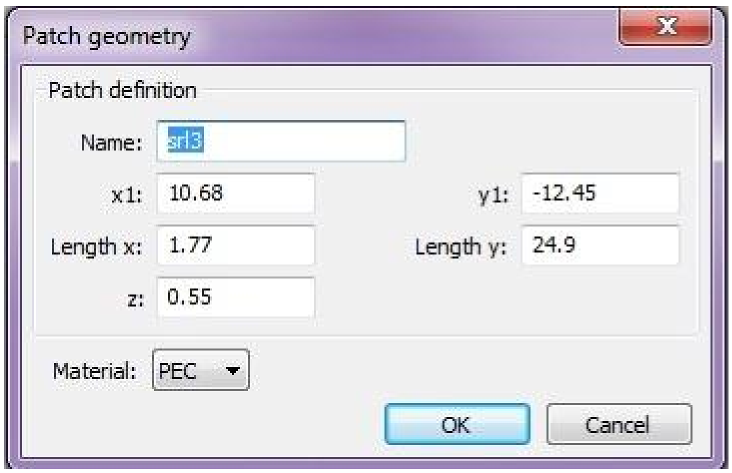
Model the Square Resonator

The next step is to model the Square Resonator on top of the substrate. Therefore, go to Geometry select patch and follow the screen shots as shown below.

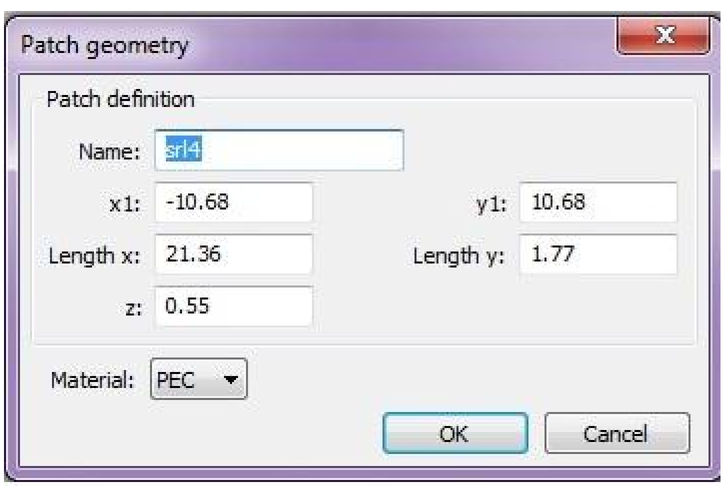




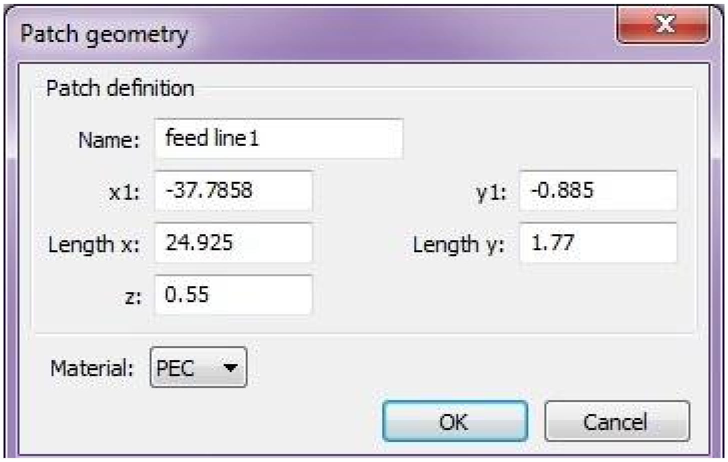
and



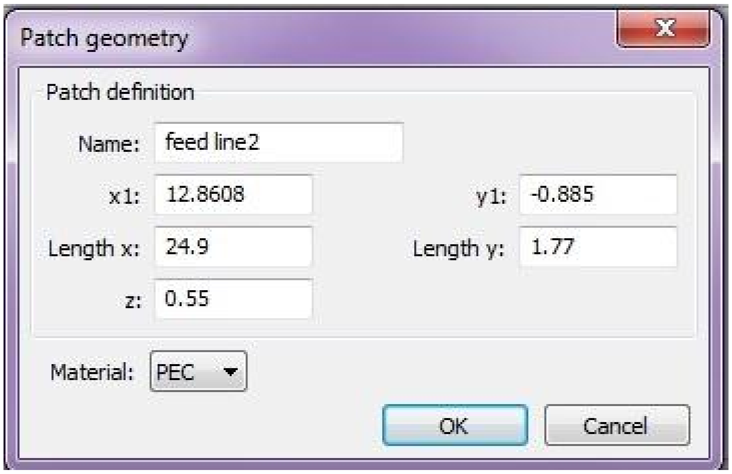
and



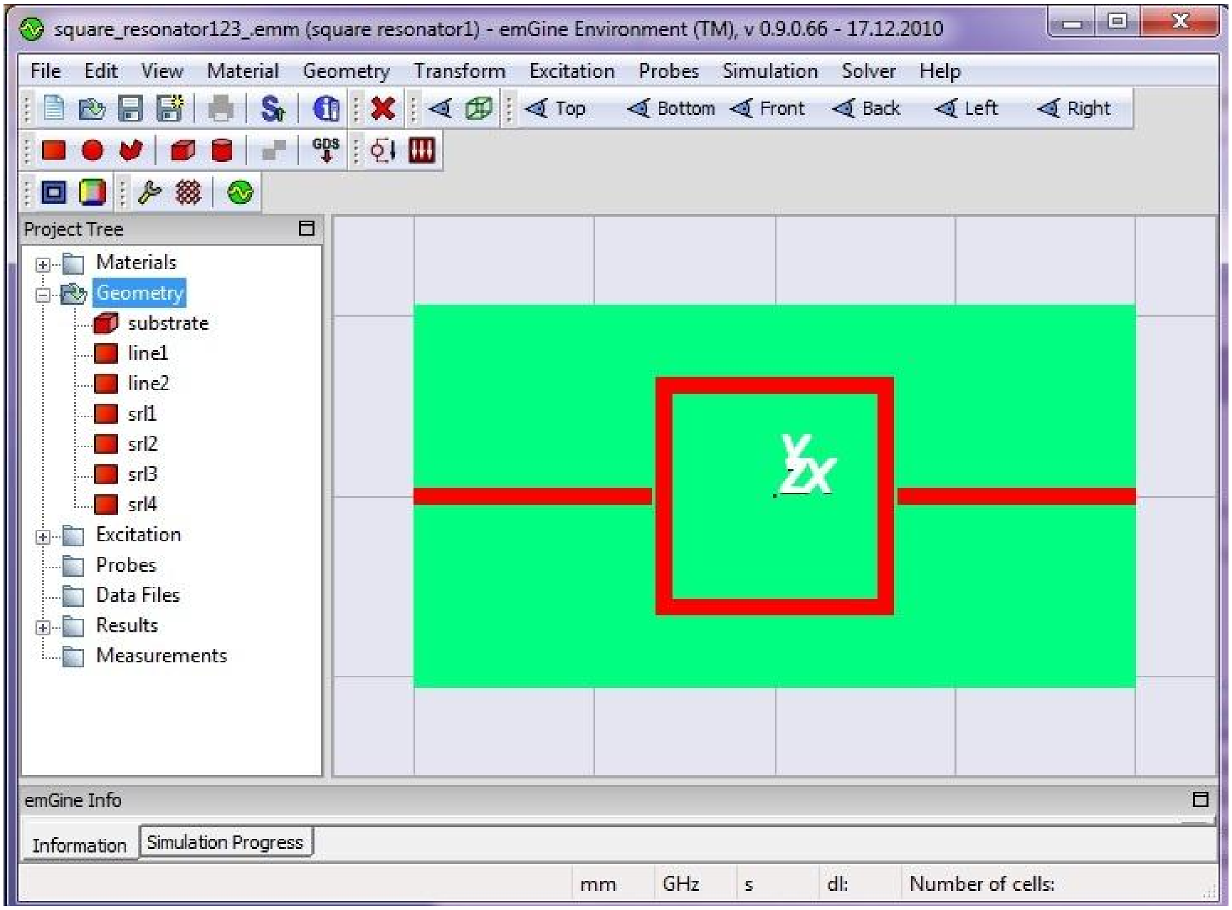
Now for designing the feed lines follow the screen shots given below



and

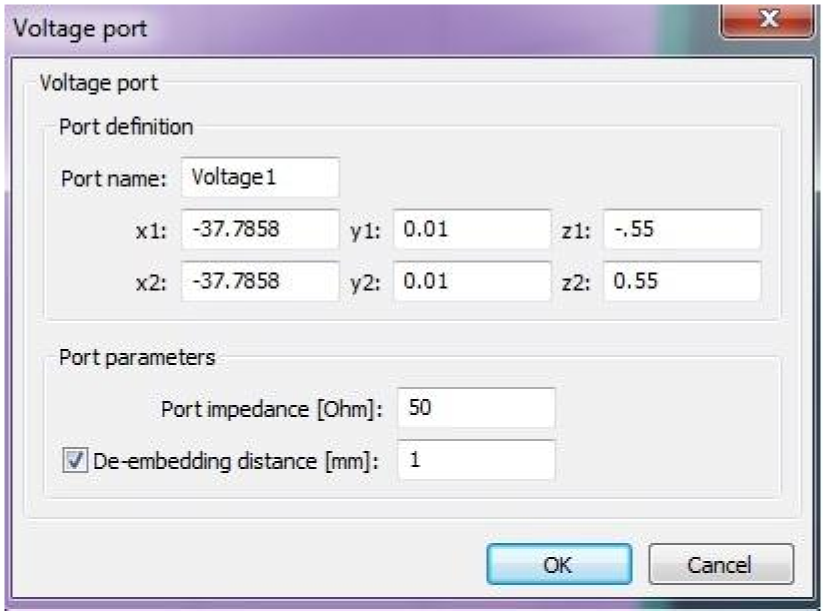


The *Material* setting of the brick must be changed to the desired Square Resonator material. Because no material has yet been defined for the Square Resonator, you should select the PEC as the material for Square Resonator from the material drop down list and in the brick creation dialog box you can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



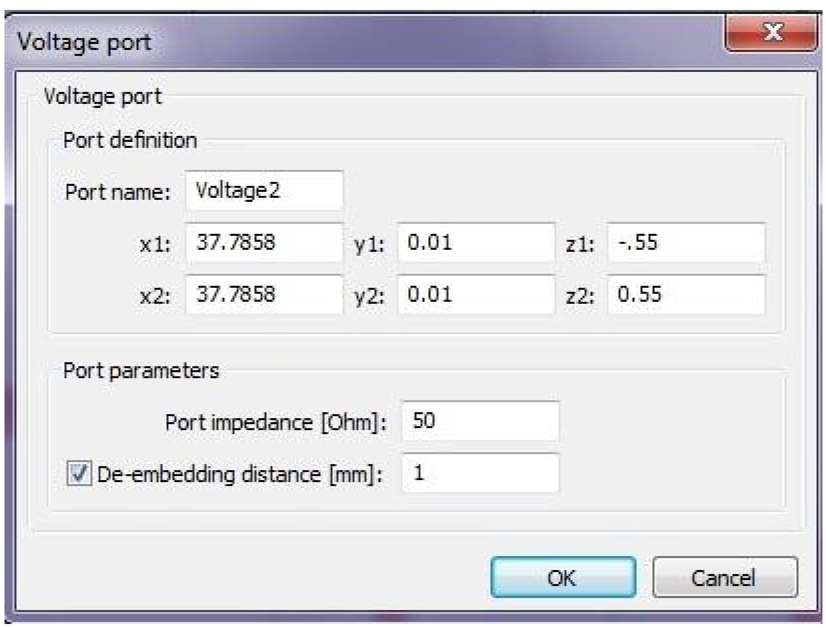
Define Ports

The next step is to add the voltage ports to the square resonator device for which the S-parameters will later be calculated. Each port will simulate square resonator 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 define the second port and press ok.

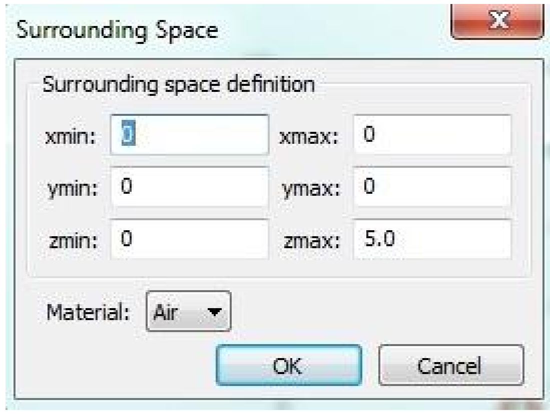
.



.

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



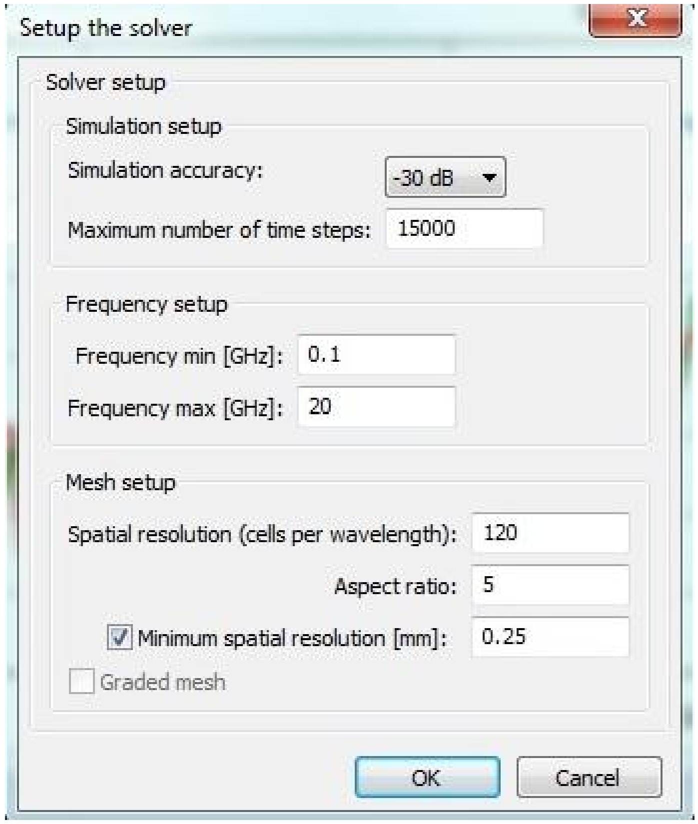
Give the values defined in the screen shot above and choose air as the surrounding material from the material drop down list and press ok for finalizing the condition.

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 as defined in the screen shot below and press ok.

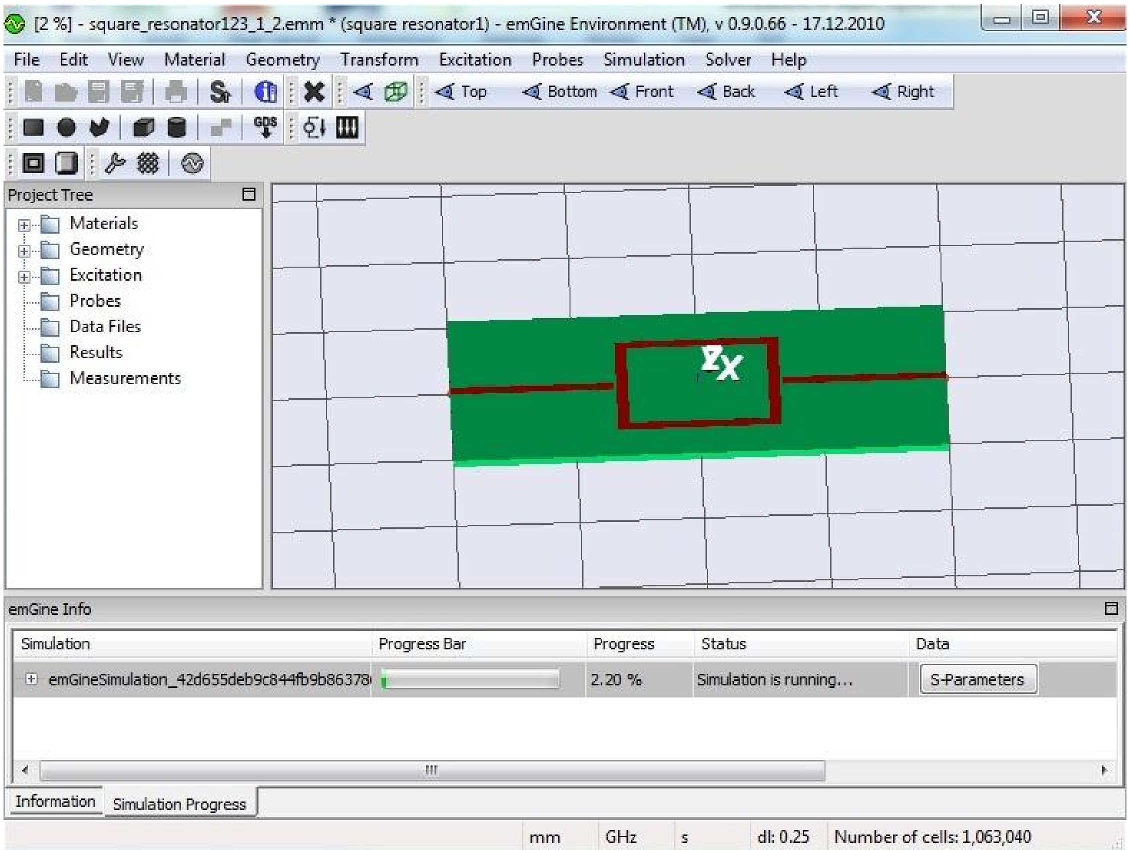
Setup the Solver

The next step is solver setting for this go to sovler 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 to 20000. Choose 15000 steps. After that define the frequency range for the simulations you can set frequency min as 0.1 GHz and frequency max as 20 GHz hence your frequency range is from 0.1 GHz to 5 GHz. Now define Special resolution as 120, Aspect ratio as 5. For finalizing the setup solver press ok.


Setup the solver
Solver setup
Simulation setup
Simulation accuracy:
-30 dB
Maximum number of time steps:
15000
Frequency setup
Frequency min [GHz]:
0.1
Frequency max [GHz]:
20
Mesh setup
Spatial resolution (cells per wavelength):
120
Aspect ratio:
5
Minimum spatial resolution [mm]:
0.25
Graded mesh
OK
Cancel

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.

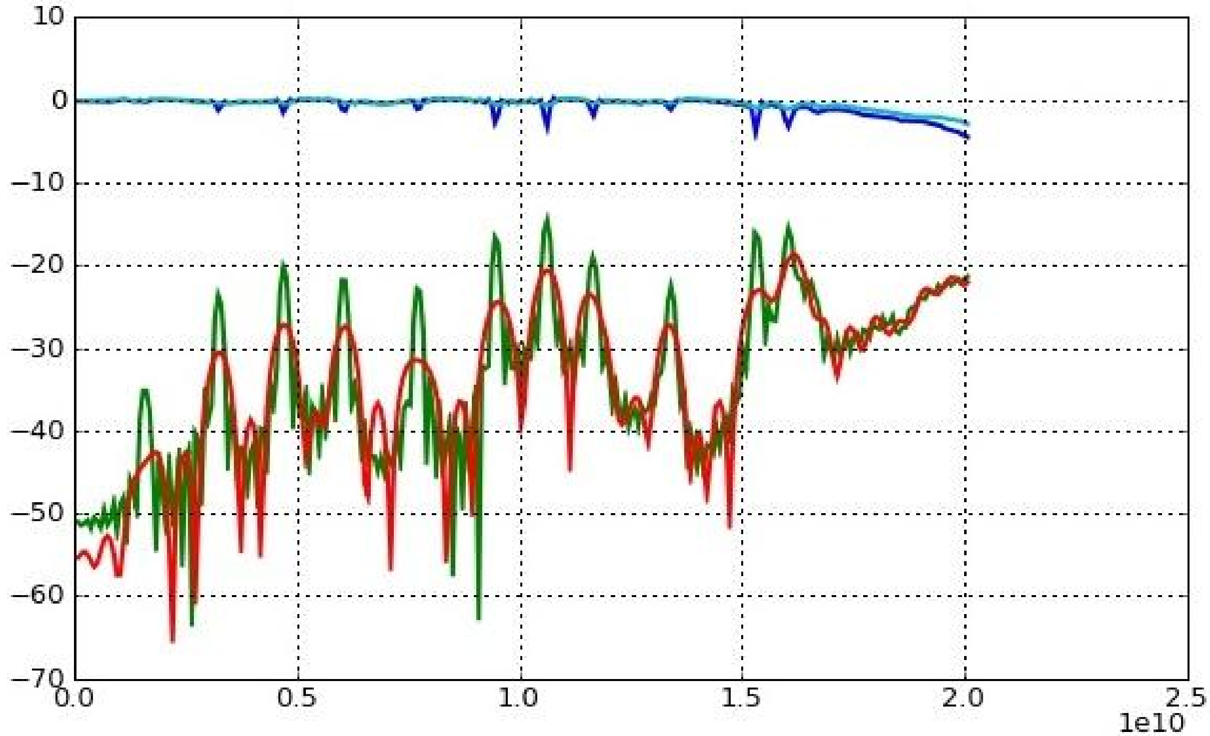


During the simulation, the Message Window will show some details about the performed simulation.

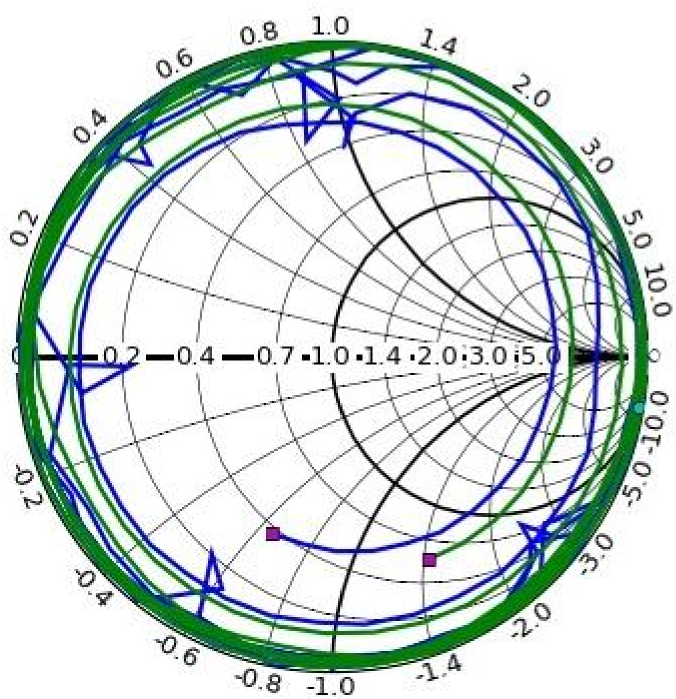
Congratulations, you have simulated the Square resonator ! Lets review the results.

S-Parameters Results

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



The computed smith chart of the Square resonator



Precautions:

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