DAYALBAGH EDUCATIONAL INSTITUTE,
DAYALBAGH, AGRA

Manual

Experiment 7

Yagi - Uda Antenna

Experiment 7

Objective:

To design the Yagi – Uda Antenna at 3 GHz

1. Calculate the length of Yagi – Uda Antenna at 1.5 GHz

To simulate the Yagi – Uda Antenna

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

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Requirement:

1. Computer facility
2. EMgine Simulation Software

Theory:

Yagi Uda Antenna

The Yagi-Uda Antenna (also known as a Yagi) is another popular type of end-fire antenna widely used in VHF and UHF bands (30 MHz to 3 GHz) because of its simplicity, low cost and relatively high gain. The most noticeable application is for home TV reception and these can be found on the rooftop of the house. A typical one is shown in fig 1.

Fig 1: A Yagi Uda TV reception antenna

Yagi and Uda were two Japanese professors who invented and studied this antenna in the 1920's. S. Uda made the first Yagi-Uda antenna and published the result in Japanese in 1926 and 1927, and the designed was further developed and published in English by his colleague Professor Yagi a year later. Since then a significant of mount of work has been done theoretically and experimentally.

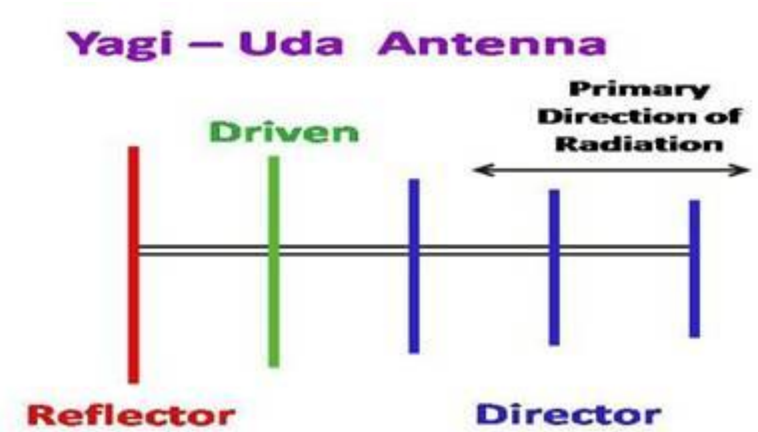

Fig 2: Configuration of Yagi Uda antenna

The main feature of this type of antenna is that it consists of three different element: the driven element, reflector and director, as shown in fig 2. Some people consider the Yagi Uda antenna an array, since it has more than one element. However, it has just one active element and feed port; all the other elements (the reflector and director) are parasitic. Thus, some people consider it an elemental antenna array. The main characteristics and design recommendations of these element can be summarized as below:

- **The driven element (feeder):** The heart of antenna. It determines the polarization and central frequency of the antenna. For a dipole, the recommended length is about 0.50 λ to ensure good input impedance to a 50 Ω feed line.

- **The reflector:** Normally slightly longer than the driven resonant element to force the radiated energy towards the front. It exhibits an inductive reactance. It has been found that there is not much improvement by adding more reflectors to the antenna, thus there is only one reflector. The optimum spacing between the reflector and the driven element is between 0.15 and 0.25 wavelength. The length of the reflector has a large effect on the front to back ratio and antenna input impedance.

- **The directors:** usually 10 to 20% shorter than the resonant driven element and appear to direct the radiation towards the front. They are of capacitive reactance. The director to director spacing is typically 0.25 to 0.35 wavelengths, with larger spacing for longer arrays and smaller spacing for shorter arrays. The number of directors determines the maximum achievable directivity and gain.

Operational Principle:

The special configuration (long reflector and short directors) has made the Yagi-Uda Antenna radiate as an end-fire antenna. The simplest three element Yagi-Uda antenna (just one director) already shows an acceptable end fire antenna pattern. The radiation towards the back seems to be blocked/reflected by the longer element, but not just by the reflector; the reflector and the director produce push and pull effects on the radiation. Induced current are generated on the parasitic element and form traveling wave structure at the desired frequency. The performance is determined by the current distribution in each element and the phase velocity of the traveling wave.

Design parameters of five element Yagi-Uda Antenna:

The length of the antenna can be calculated by using the formula:

$\lambda = c/f$

the wire of 2 mm diameter is used as the antenna element and the space between the dipole is 2 mm. the separation between the dipole is .1λ. the length of reflector and director can be calculated by

Element of Yagi Uda antenna	Length	Separation
Reflector	0.55λ	0.1 λ
Driven element	λ/2	0.1λ
Director	0.45λ, 0.40 λ, 0.35 λ	0.1 λ

Formula Used:

To design the Yagi-Uda antenna, we have to calculate the wavelength which is equal to length of the Yagi Uda antenna.

Procedure for calculation:

Expression for wavelength of the driven element of Yagi-Uda antenna is:

$\lambda = c/f$

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Example: Calculate the wavelength (length) of Yagi-Uda antenna at 3 GHz .

Given Parameters:

Frequency f = 3 GHz

Diameter of metallic wire = 2 mm

Space between driven element = 2 mm

Speed of light c = 3×10^8

Calculate the wavelength λ:

$\lambda = c/f$

$$\lambda = \frac{3 \times 10^8}{3 \times 10^9} = 0.1\ m\ or\ 100\ mm$$

Length of driven element = $\lambda/2$ = 50 mm

Length of reflector = 0.55λ = 55 mm

Length of director 1 = $0.45\ \lambda$ = 45 mm

Length of director 2 = $0.40\ \lambda$ = 40 mm

Length of director 3 = $0.35\ \lambda$ = 35 mm

Separation between reflector, driven element and directors = $.1\lambda$ = 10mm

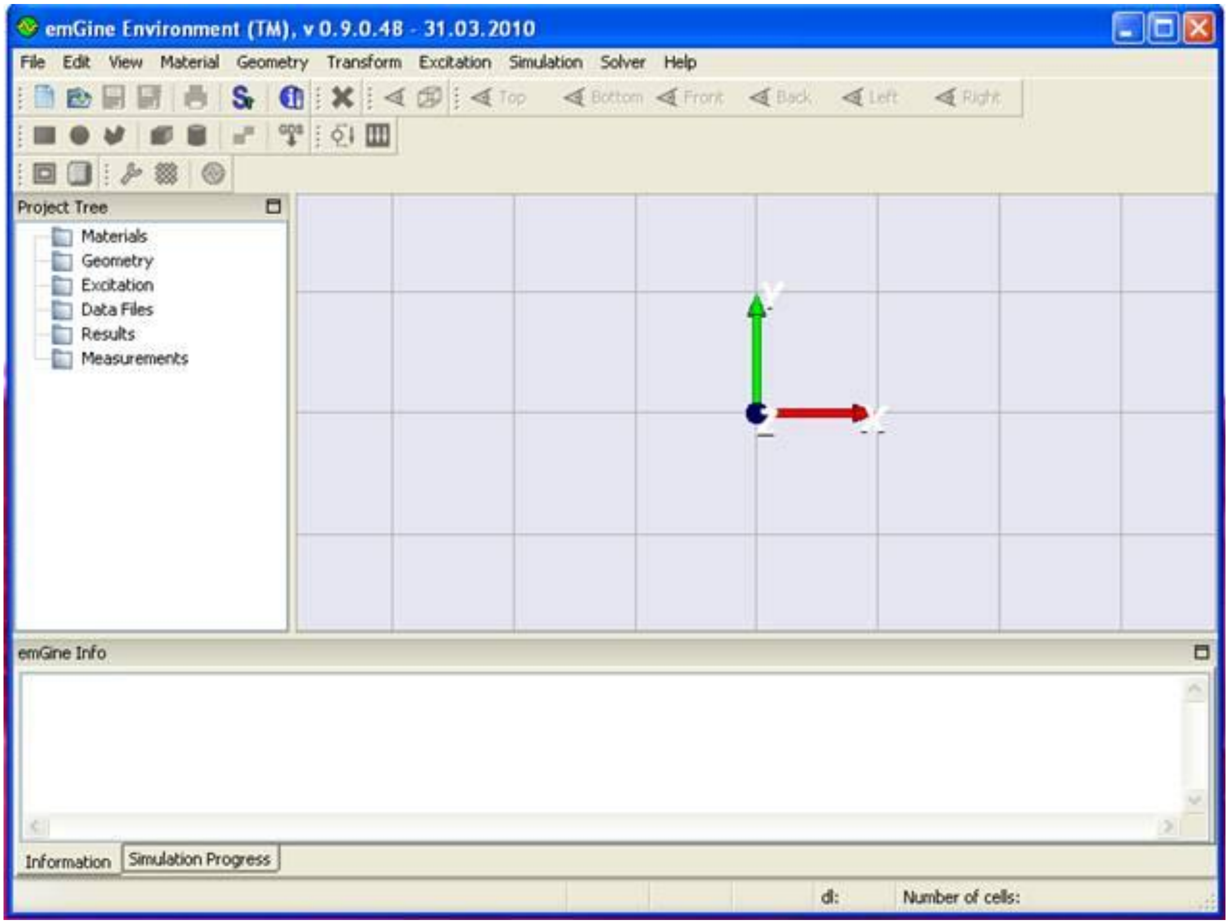
Procedure for simulation:

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 Yagi-Uda antenna. The following explanations on how to model and analyze this device can be applied to other planar devices, as well.

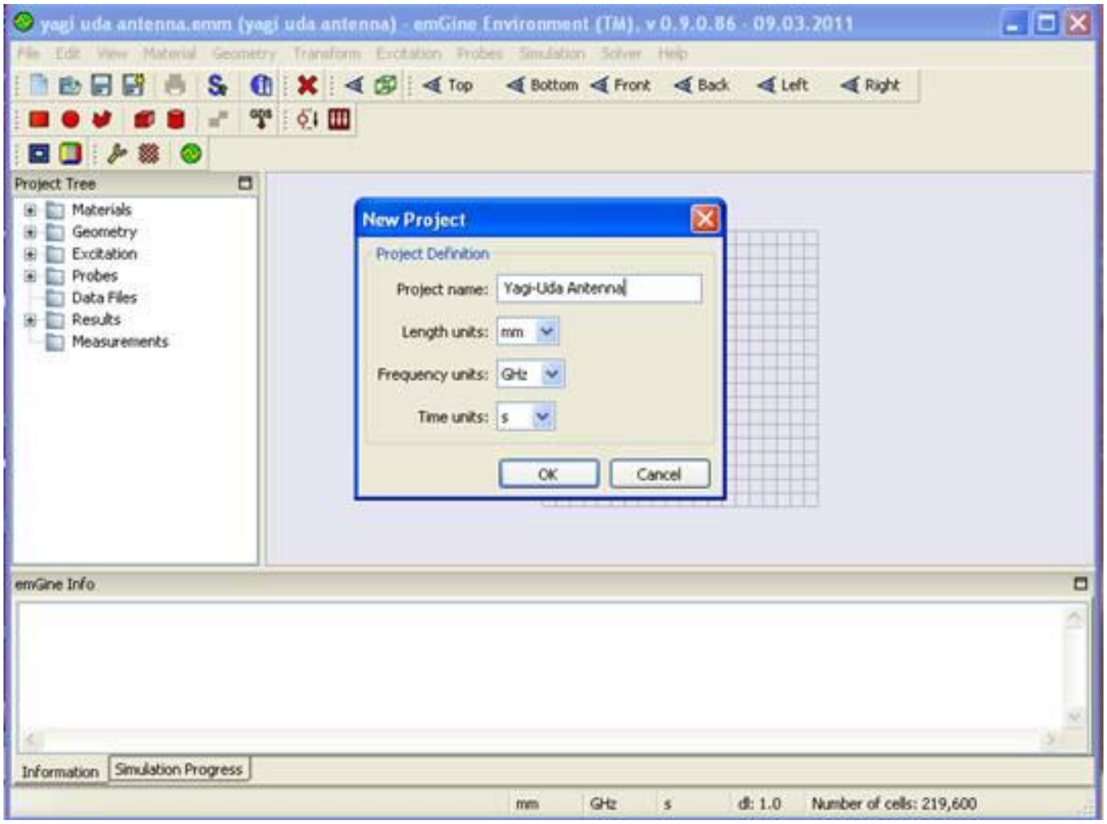
Geometric Construction Steps

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.

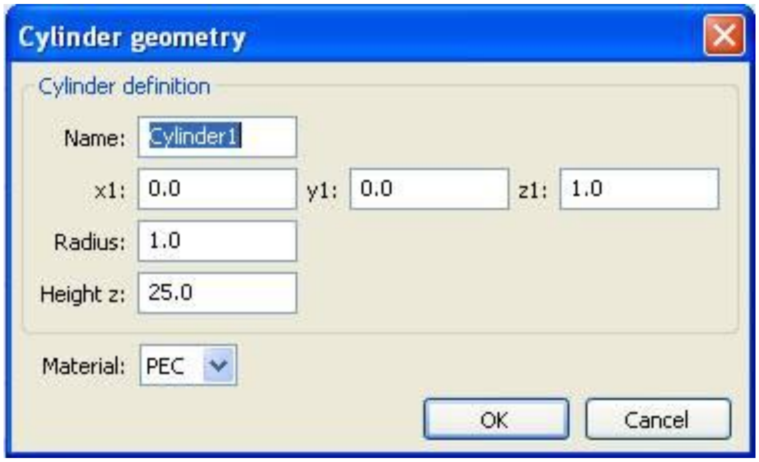
Set the Working Planes Properties

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. As we know that Yagi-Uda antenna is a metal wire made antenna, hence we choose the material of the wire is PEC and the material properties of PEC is already defined. Hence there is no need to define any new material.

Draw the Driven element

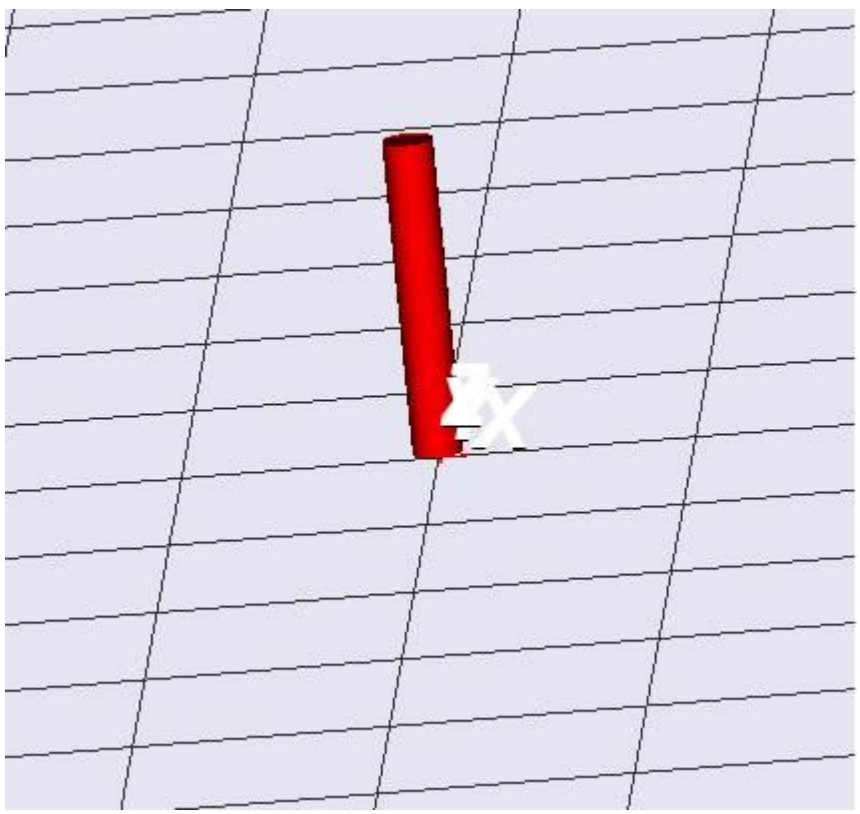
The first step is to design a driven element of cylinder for the modeling of wire type Yagi-Uda antenna. This can be easily achieved by creating a cylinder made of the PEC material. Please activate the cylinder creation mode (*Geometry - Cylinder*).

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

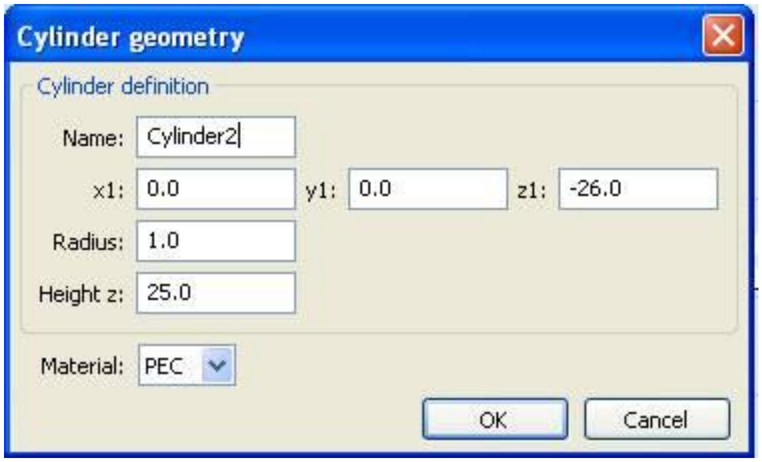


The transversal coordinates are given above in the screen shot. Please check all these settings carefully. If you encounter any mistake, please change the value in the corresponding entry field. You should now assign a meaningful name to the brick by entering e.g. driven in the *Name* field.

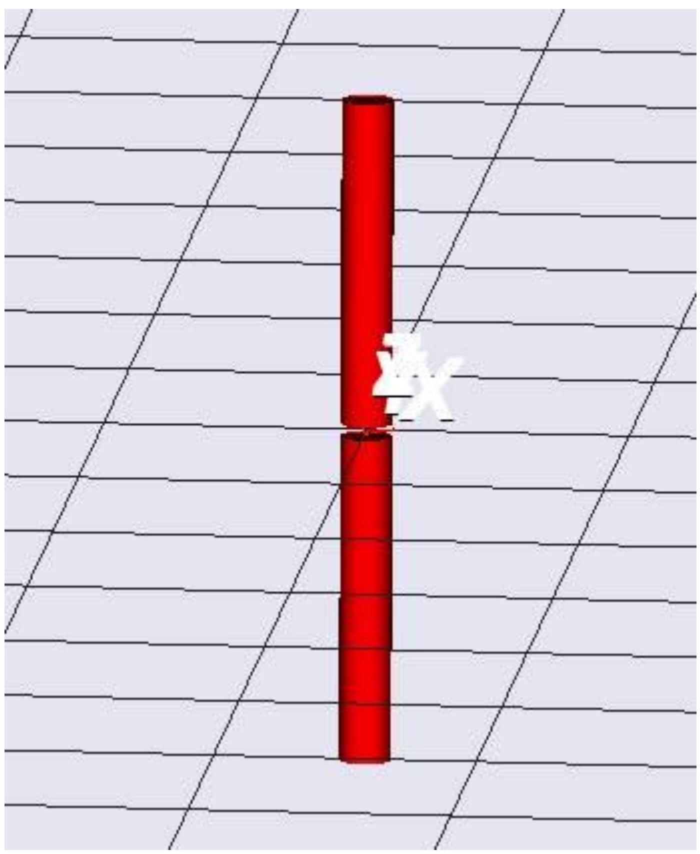
The *Material* setting of the cylinder must be changed to the desired material. Because no material has yet been defined for the cylinder, you should open the layer definition dialog box by selecting PEC from the *Material* dropdown list. Now in the cylinder creation dialog box you can press the *OK*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



Since we know that Yagi-Uda antenna is a straight collinear wire with a small space between them hence design the other part of Yagi-Uda antenna. Select the cylinder again. Give the appropriate design parameters as shown in screen shot below.



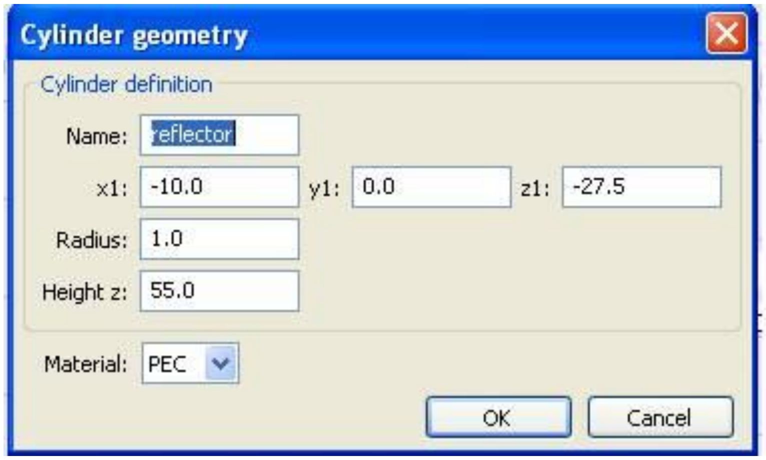
Your screen should now look as follows



Draw the Reflector

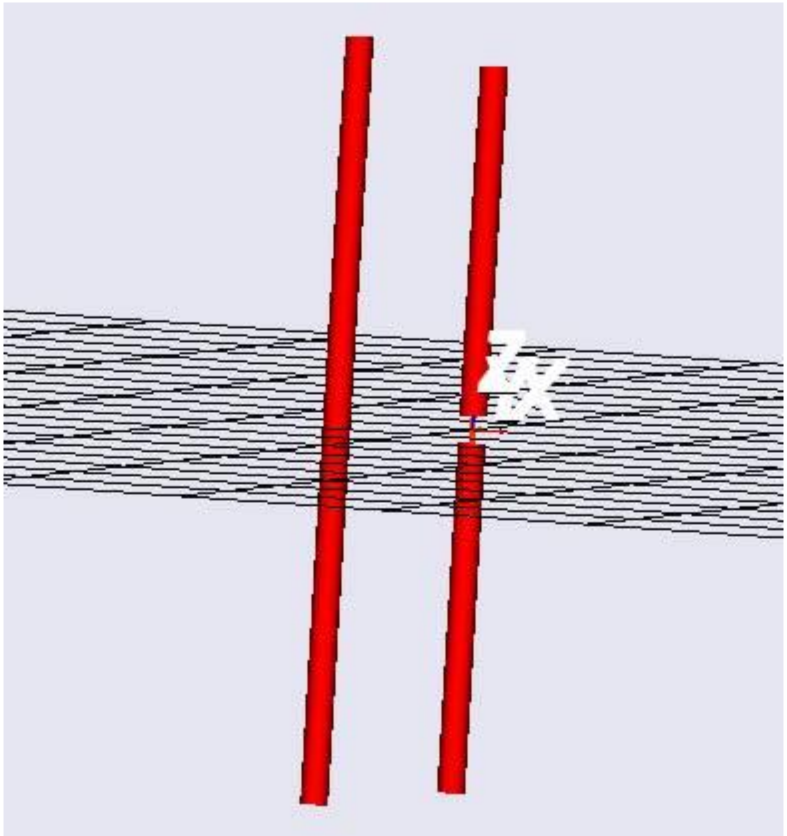
The first step is to design a reflector of cylinder for the modeling of wire type Yagi-Uda antenna. This can be easily achieved by creating a cylinder made of the PEC material. Please activate the cylinder creation mode (*Geometry - Cylinder*).

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



The transversal coordinates are given above in the screen shot. 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. reflector in the *Name* field.

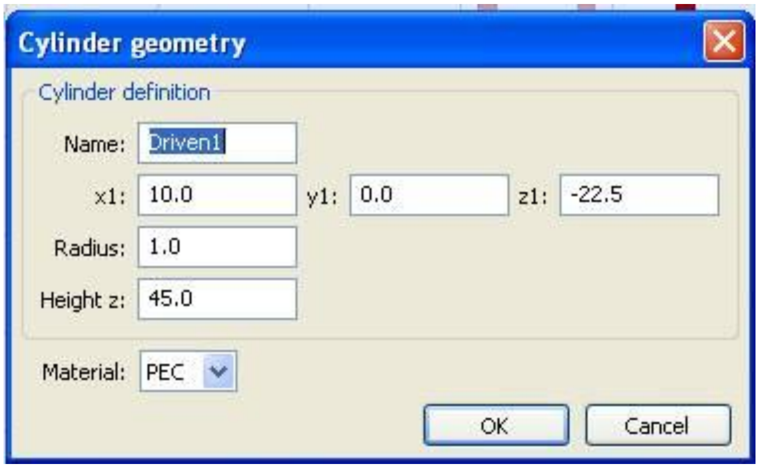
The *Material* setting of the cylinder must be changed to the desired material. Because no material has yet been defined for the cylinder, you should open the layer definition dialog box by selecting PEC from the *Material* dropdown list. Now in the cylinder creation dialog box you can press the *OK*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

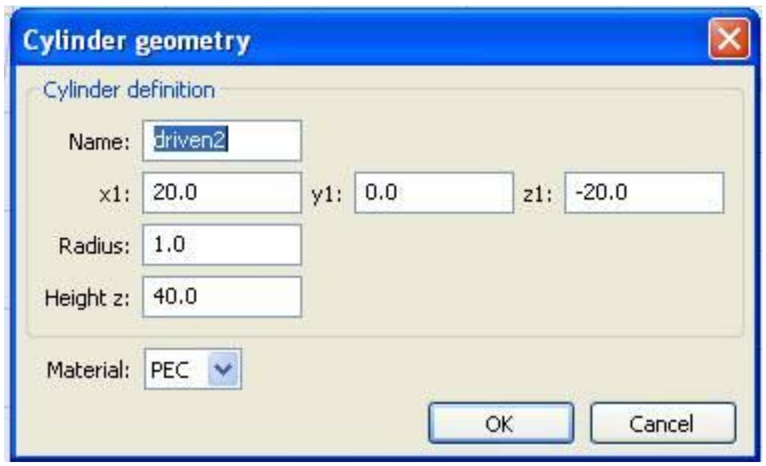


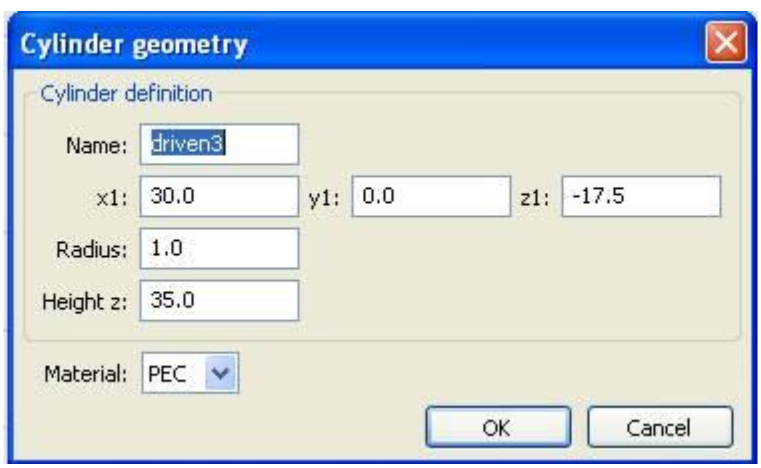
Draw the Director

The first step is to design a director of cylinder for the modeling of wire type Yagi-Uda antenna. This can be easily achieved by creating a cylinder made of the PEC material. Please activate the cylinder creation mode (*Geometry* - *Cylinder*).

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

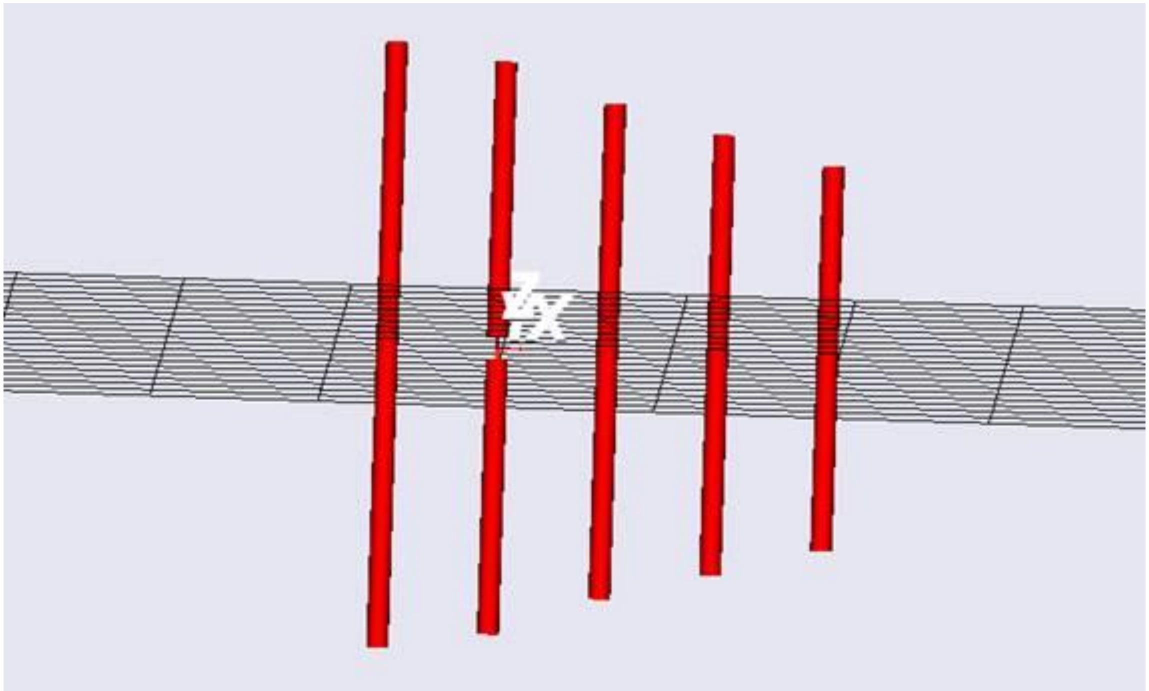






The transversal coordinates are given above in the screen shot. Please check all these settings carefully. If you encounter any mistake, please change the value in the corresponding entry field. You should now assign a meaningful name to the brick by entering e.g. director in the *Name* field.

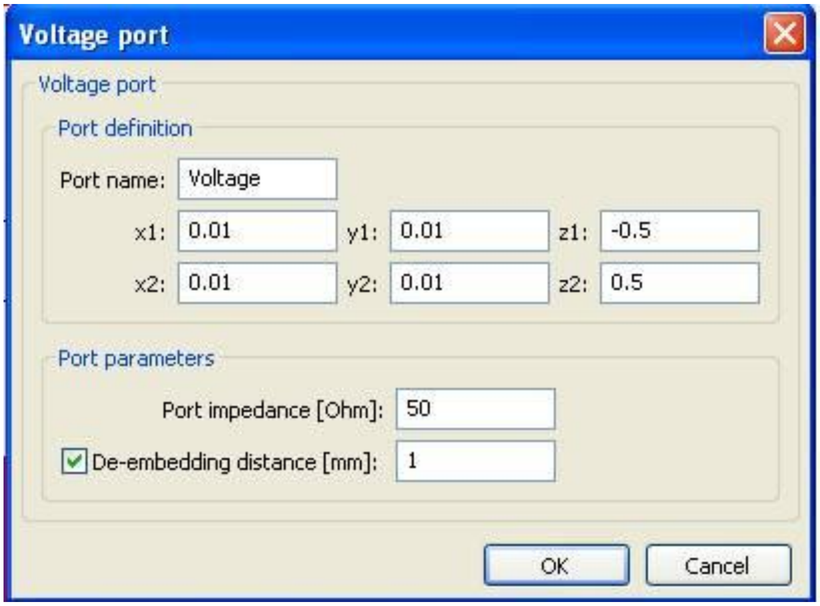
The *Material* setting of the cylinder must be changed to the desired material. Because no material has yet been defined for the cylinder, you should open the layer definition dialog box by selecting PEC from the *Material* dropdown list. Now in the cylinder creation dialog box you can



press the *OK* button to finally create the PEC cylinder. Your screen should now look as follows

Define Ports

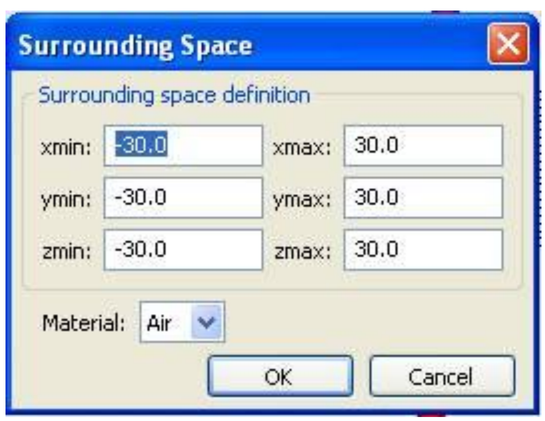
The next step is to add the ports to the Yagi-Uda antenna for which the S-parameters will later be calculated. Only on port will simulate Yagi-Uda antenna structure that is connected in the small space between two PEC wires. To define the port, go to excitation and select voltage port. A dialog box will open then in the dialog box give the port name as port1 and then define the coordinates as shown below and press ok to finalize.



Note: Yagi-Uda antenna is a single port device.

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



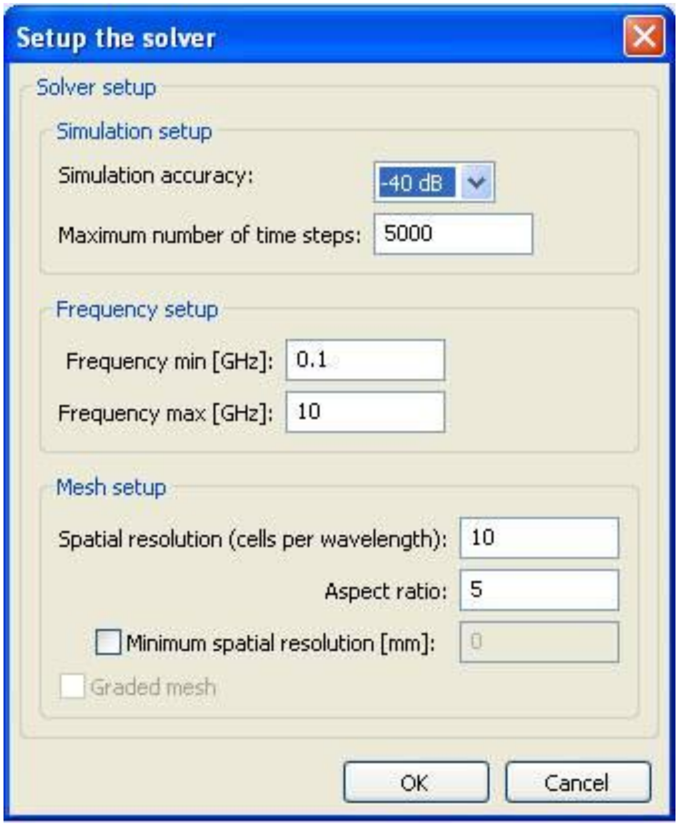
Give the values defined in the screen shot above and choose air as the surrounding material from the material drop down list and press ok for finalizing the condition.

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.

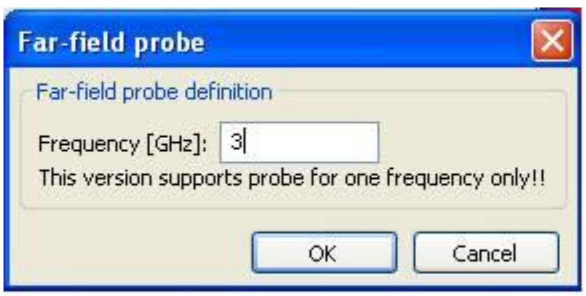
Setup the Solver

The next step is the solver setting, for this go to solver and by pressing setup a dialog will open. In this box simulation accuracy should be -80dB. You can choose maximum number of the time steps between 500 and 10000. Choose 6000 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.



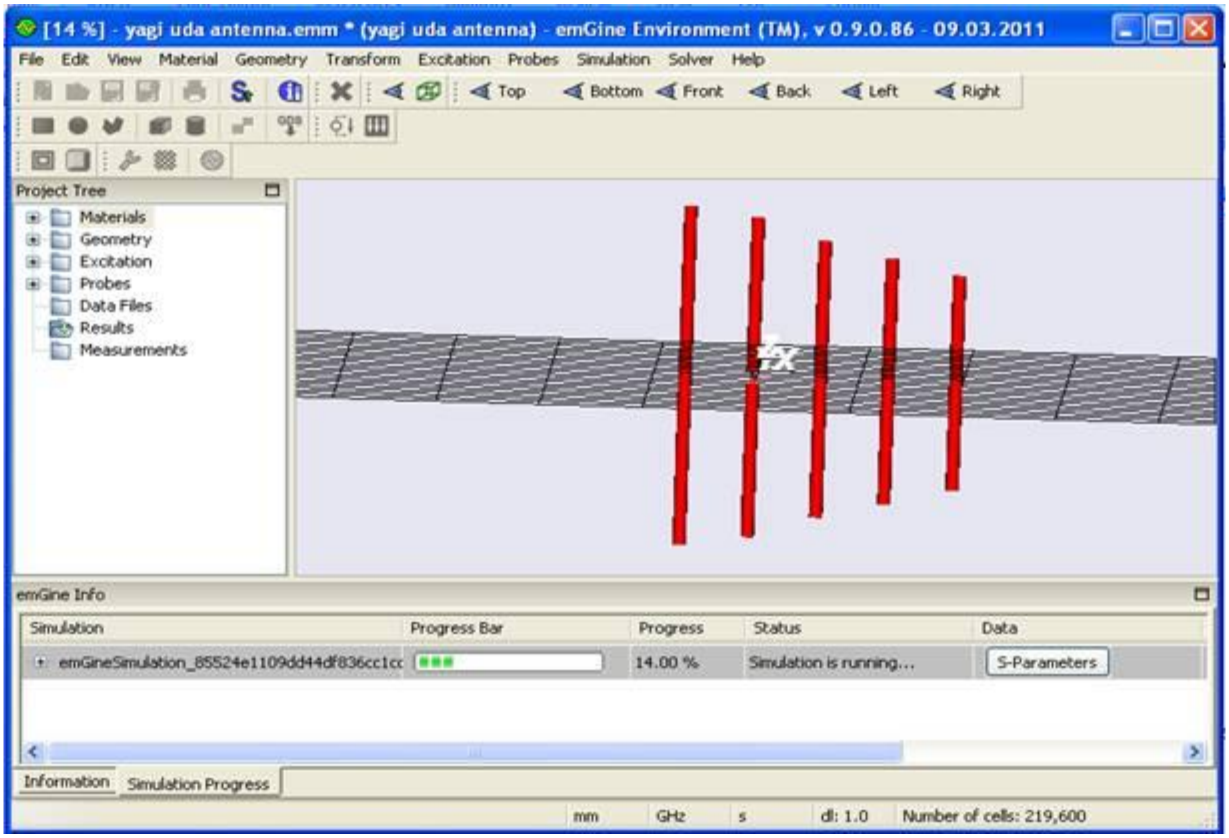
Define the Far-Field

Go to probes and choose Far Field then an Far Field probe setup box will open, Choose 3 GHz as frequency and 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.



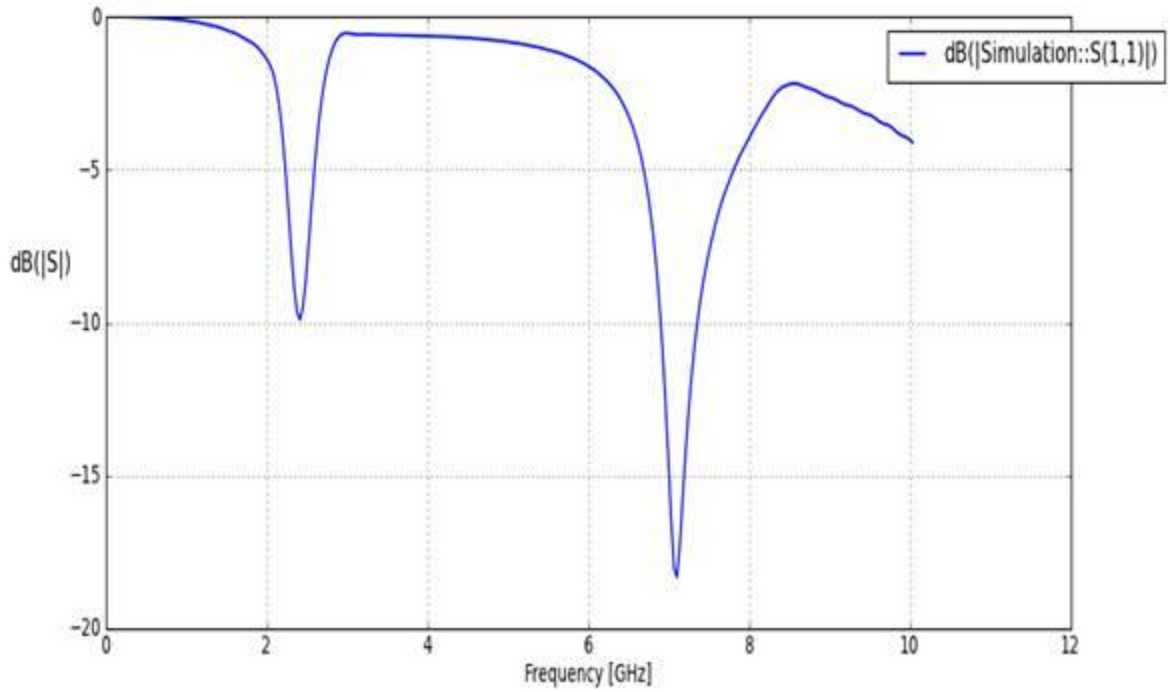
During the simulation, the Message Window will show some details about the performed simulation.

Congratulations, you have simulated the Yagi-Uda antenna ! Let's review the results.

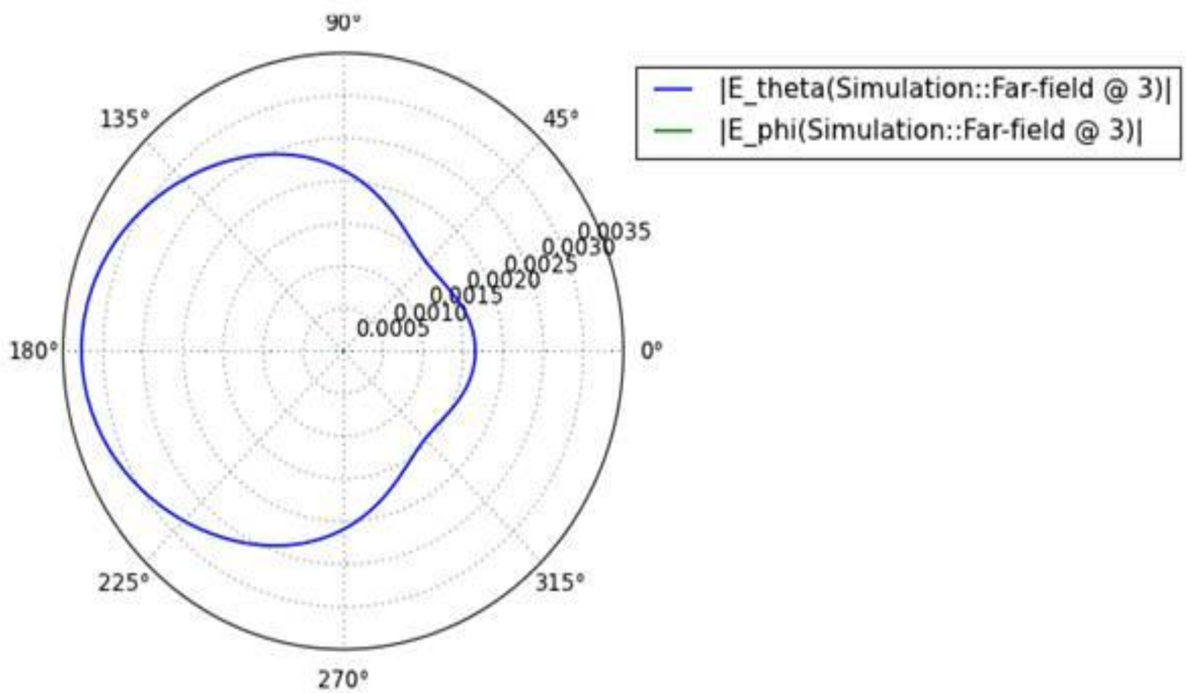
Results:

S-Parameters Results

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



The computed far field at 3 GHz – of the Yagi-Uda antenna



Precautions:

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