EM.Libera
Tutorial Lessons

EMAG Technologies Inc.
775 Technology Dr. St. 300, Ann Arbor, MI 48108
Phone: (734) 996-3624 Fax: (734) 996-3623

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EM.Libera Tutorial Lesson 2

Designing a Yagi-Uda Dipole Array

Table of Contents

2.1 What You Will Learn

In this tutorial you will use a wizard to build and analyze a multi-element Yagi-Uda wire antenna array. You will learn how to perform a parametric sweep simulation using the project's design variables.

EM.Libera Manual:

http://www.emagtech.com/wiki/index.php/EM.Libera

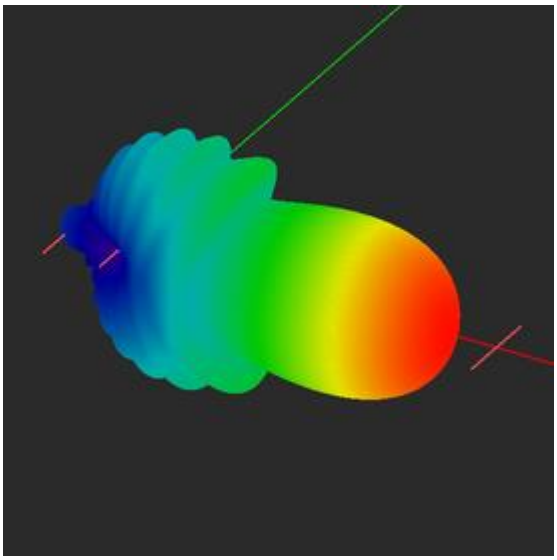
EM.Libera Tutorial Gateway:

http://www.emagtech.com/wiki/index.php/EM.Cube#EM.Libera_Documentation

Download projects related to this tutorial lesson:

http://www.emagtech.com/downloads/ProjectRepo/EMLibera_Lesson2.zip

Tutorial Project: Designing a Yagi-Uda Dipole Array



Objective: In this project, you will build and analyze a Yagi-Uda dipole array using EM.Libera's Wire MoM solver.

Concepts/Features:

- CubeCAD
- Array object
- Gap Source
- Mesh Density
- Current Distribution
- Radiation Pattern
- S-Parameters
- Adaptive sweep

Minimum Version Required: All versions

2.2 Getting Started

Start a new project with the following parameters:

Starting Parameters	
Name	EMLibera_Lesson2
Length Units	Millimeters
Frequency Units	GHz
Center Frequency	2.4GHz
Bandwidth	1GHz

2.3 The Yagi-Uda Array Design

A Yagi-Uda array is an end-fire array, which is typically made of an exciter element, a reflector element and several director elements. The lengths of all the elements vary around a half wavelength. The following table shows the electrical lengths and spacing of a typical design:

Element	Length	Distance from Exciter
Exciter	$0.47\lambda_0$	0
Reflector	$0.5\lambda_0$	$0.25\lambda_0$
Director	$0.406\lambda_0$	$0.34\lambda_0$

Figure 1 shows the Yagi-Uda array schematic. In this design, the spacing between the director elements is uniform and equal to $0.34\lambda_0$. The radius of all wires is $0.003\lambda_0$. In this project, $f_0 = 2.4$GHz, and the free-space wavelength is $\lambda_0 = 125$mm.

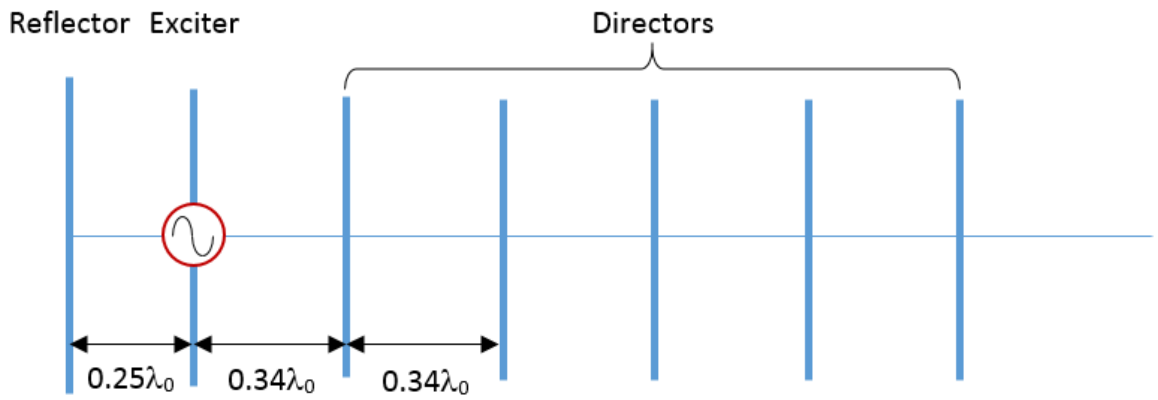


Figure 1. *The Yagi-Uda array schematic.*

2.4 Constructing the Array Geometry

Click on the **Yagi-Uda Wizard** button of the **Wizard Toolbar** (Figure 2) or select the menu item **Tools** → **Antenna Wizards** → **Yagi-Uda Array**.

Figure 2. *EM.Libera's Wizard Toolbar.*

The Yagi Wizard Quick Settings dialog will open up. Keep the default settings for **Array Direction**, **Dipole Polarization**, and **No. Elements** as X, Y, and 5, respectively, in the dialog window as shown in Figure 3.

The geometry of a 7-element Yagi-Uda dipole array appears at the center of the project workspace (see Figure 4).

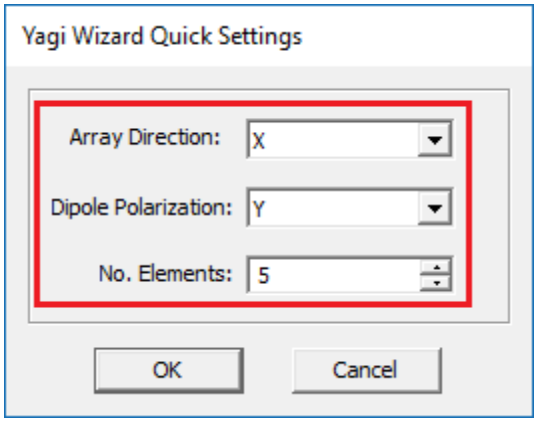


Figure 3. *EM.Libera's Yagi Wizard Quick Settings dialog window.*

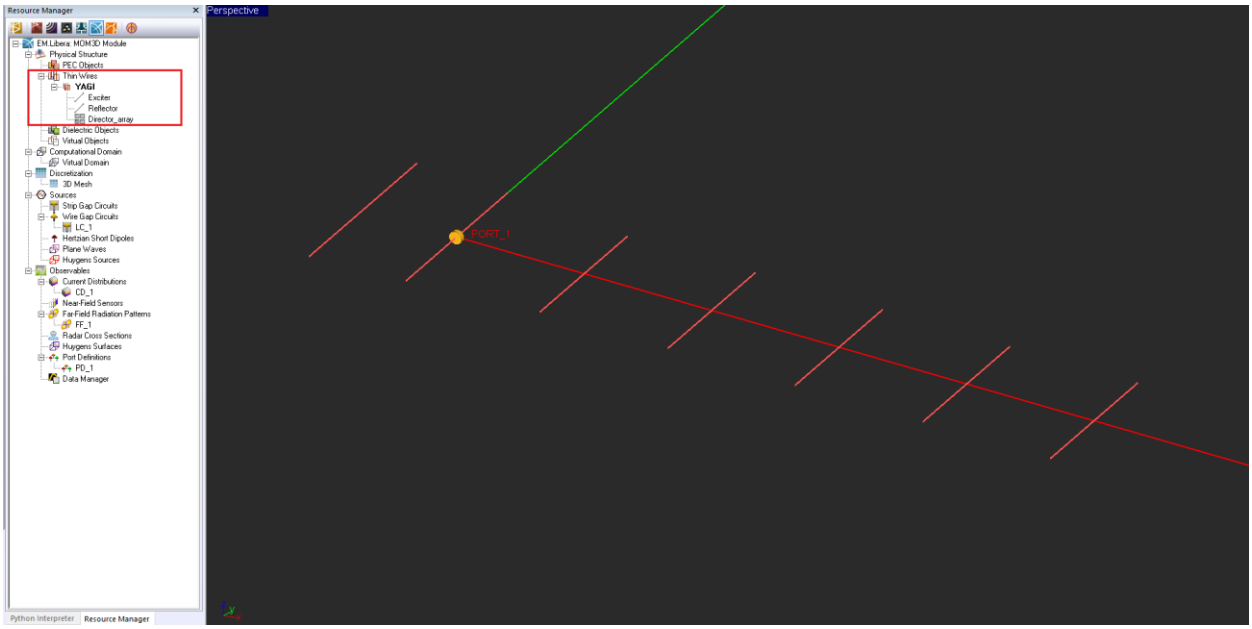


Figure 4. *The dipole antenna geometry in the project workspace and the highlighted additions to the navigation tree.*

Three items are added under a thin wire group called "YAGI" as follows:

- **Exciter**: a line object,
- **Reflector**: a line object,
- **Director_array**: an array of line objects.

The line array contains five equally spaced elements. Select "Director_array" in the navigation tree, right-click on its name and select **Properties...** from the contextual menu to open the array dialog (Figure 5).

As you can see from the array properties, $N_x \neq 1$ and $N_y = N_z = 1$, representing an X-directed linear array (Figure 6). If you click the **Primitive** button of the array dialog, another property dialog opens up which belongs to the original geometric object the wizard used to create the array object (Figure 7).

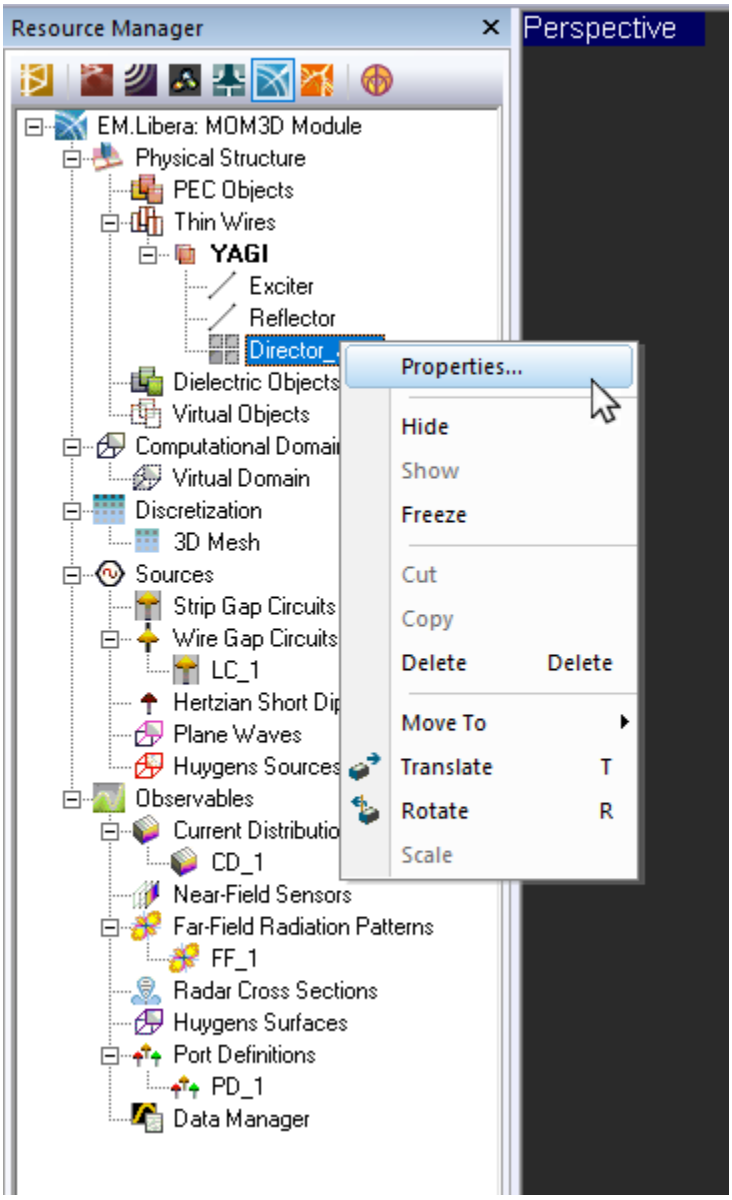


Figure 5. *Opening the property dialog of the "Director_array".*

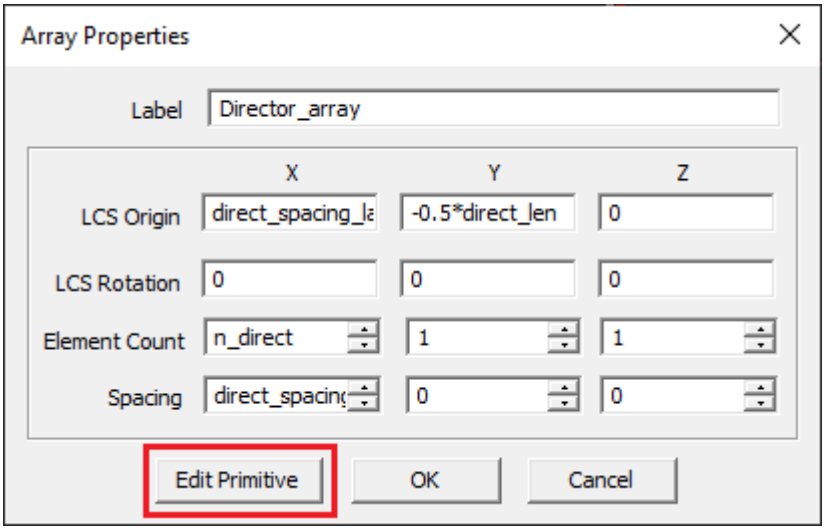


Figure 6. *The array object's property dialog.*

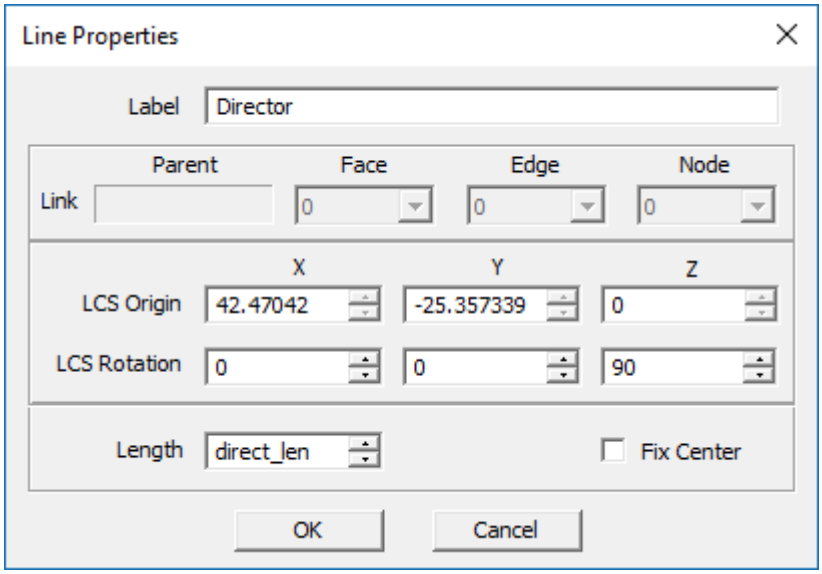


Figure 7. *The property dialog of the primitive line object.*

Open the Variables Dialog and review all the variables used in the definition of the Yagi-Uda array (Figure 8).

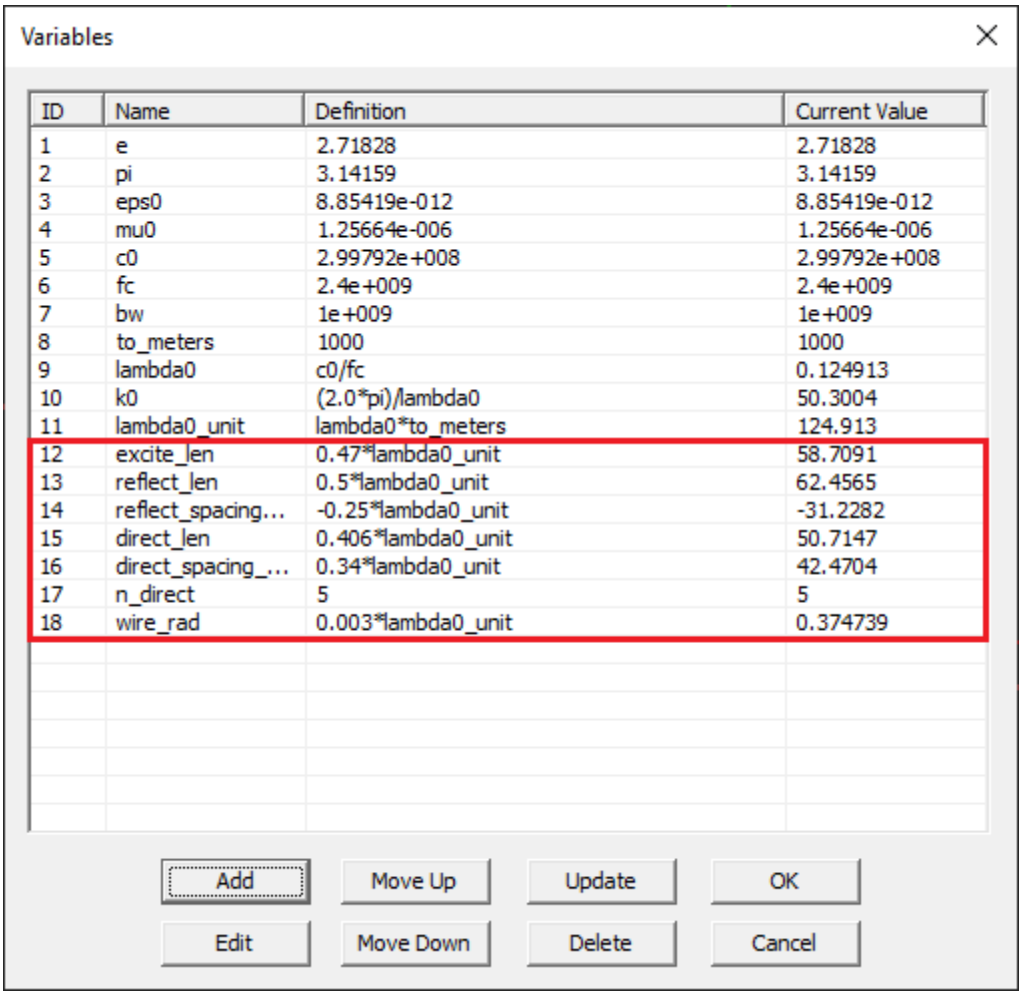


Figure 8. *The Variables dialog showing the Yagi-Uda array parameters.*

2.5 Examining the Source, Observables & Mesh Settings

Source

The wizard placed a wire gap source at the center of the "Exciter" line object (see Figure 9):

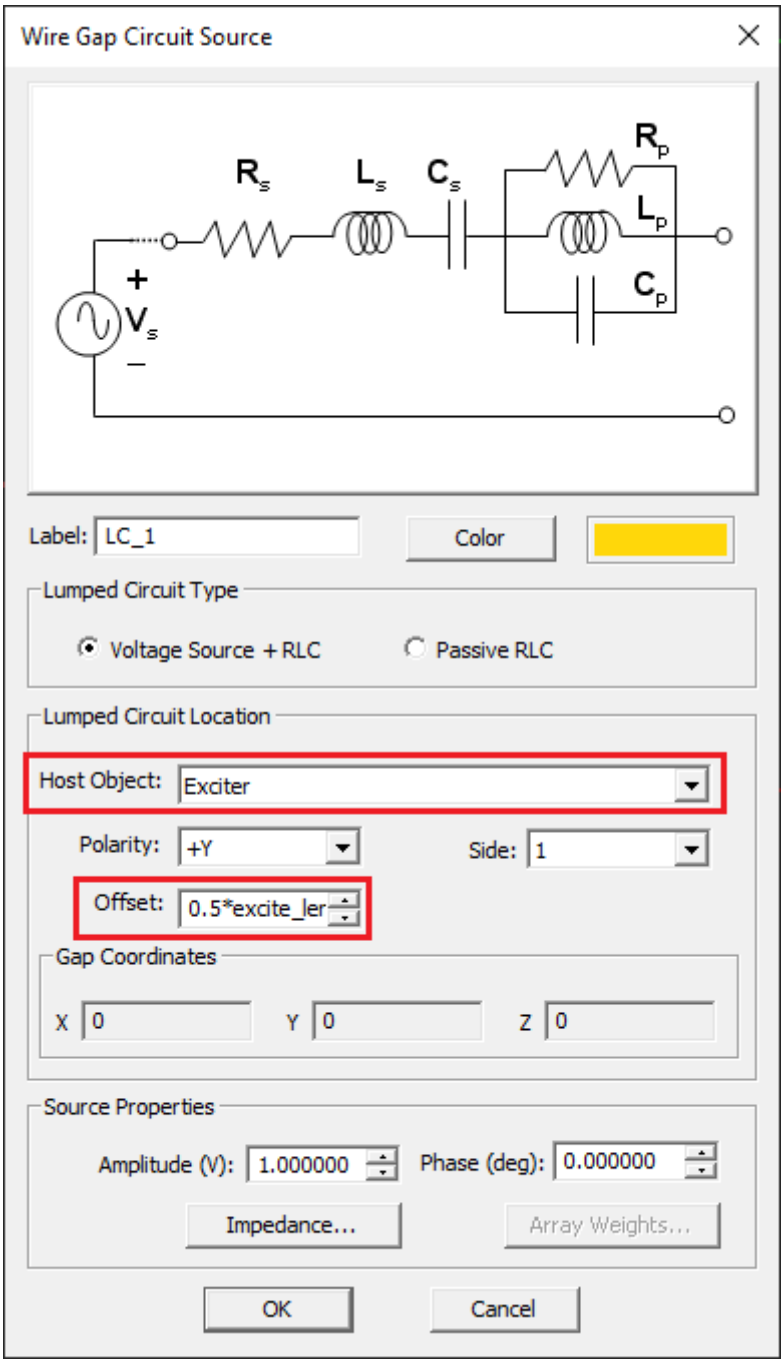


Figure 9. *The property dialog of the exciter's gap source.*

Current Distribution

The wizard also defined a default current distribution observable called "CD_1".

Far-Field Radiation Pattern

The wizard also initiated Far-Field Radiation Pattern observable called "FF_1" with 1° **Step Theta** and **Step Phi** angle increments. Open the Radiation Pattern dialog by right-clicking on "FF_1" in the navigation tree and selecting **Properties...** from the contextual menu. Check the boxes labeled **Half Power Beam Width** and **Front-to-Back Ratio** in the section titled **Additional Radiation Characteristics** (Figure 10).

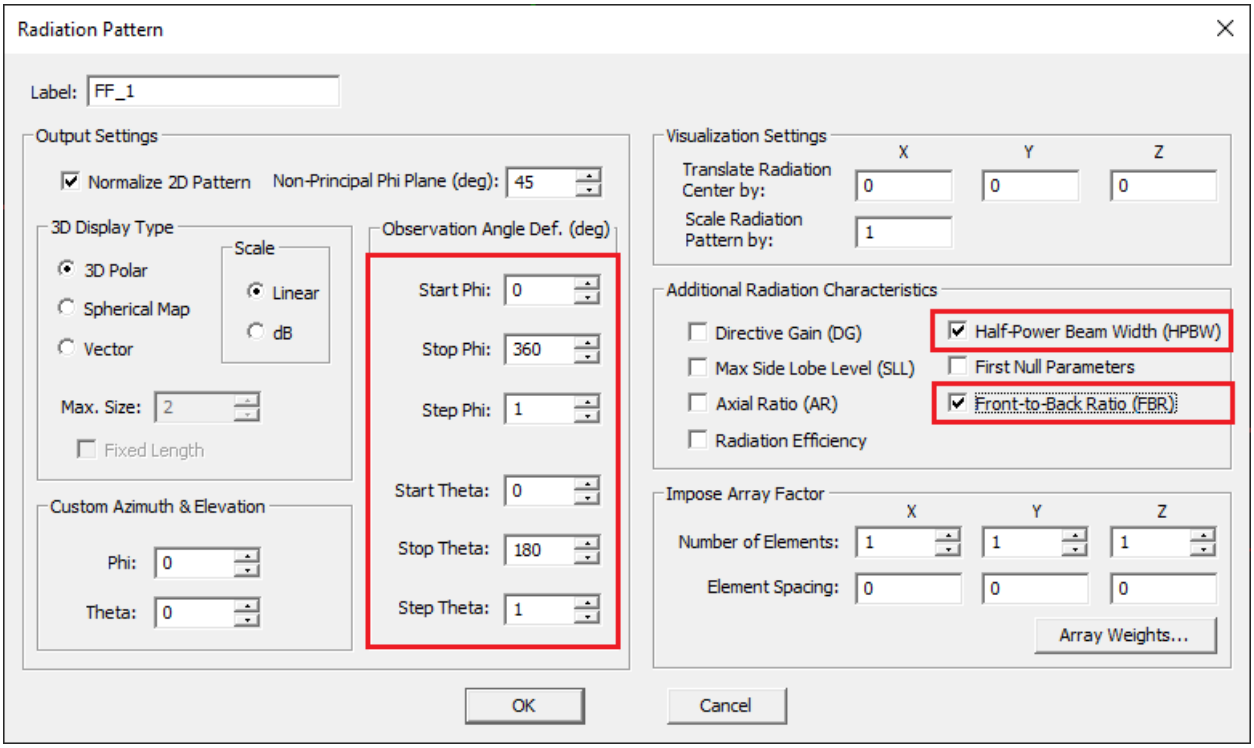


Figure 10. *The Radiation Pattern dialog.*

Mesh Density

The wizard also set the mesh density equal to an unusually high value of 100 Cells per effective wavelength. Open the Mesh Settings dialog and verify this (Figure 11). The performance of the Yagi-Uda array greatly depends on the precision of the lengths and spacing of its elements. Considering the fact that these lengths and spacings are fairly close to each other, a high-resolution mesh is naturally expected.

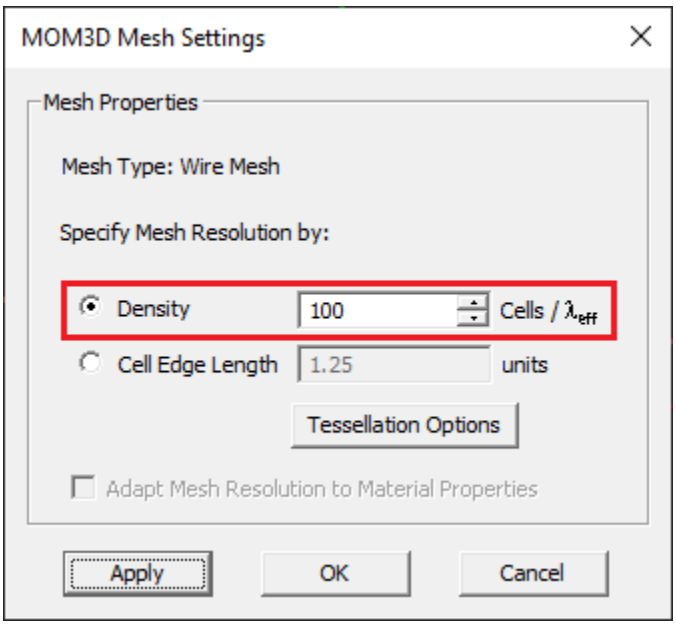


Figure 11. *EM.Libera's Mesh Settings dialog.*

2.6 Running a WMOM Analysis of the Yagi-Uda Array

Run a single-frequency Wire MoM analysis of the Yagi-Uda array. Note that even though you have a multi-element antenna array, your structure is indeed one-port. At the end of the simulation, the port characteristics of the array are reported as follows:

S11: -0.066842 + 0.022391j

S11(dB): -23.037127

Y11: 0.015227 - 0.000685j

Z11: 65.539975 + 2.949646j

Visualize the total electric current distribution ("JsMagTotal") on the array structure (Figure 12). From Figure 12, you can see that the exciter and reflector elements are much hotter than the director elements.

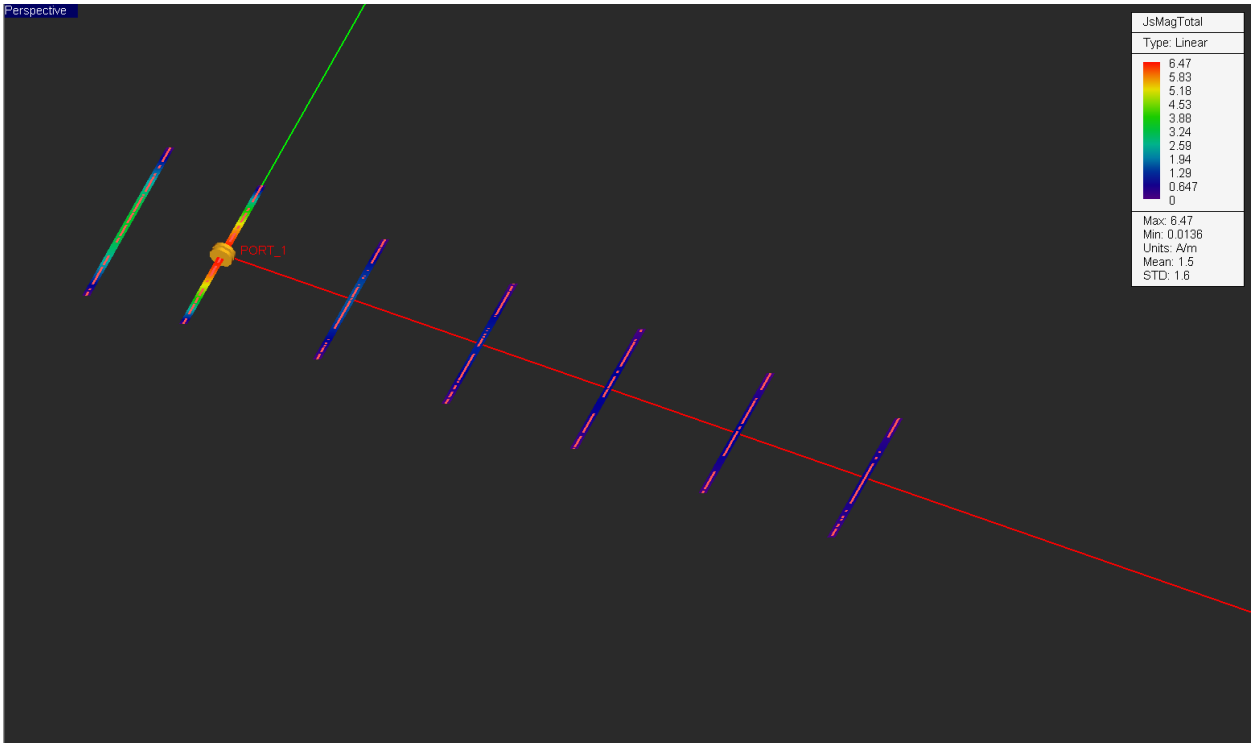


Figure 12. *The total electric current distribution on the Yagi-Uda antenna array.*

Then, visualize the 3D radiation pattern of the Yagi-Uda array. The directivity of the antenna array is computed to be D0 = 7.461 (see Figure 13).

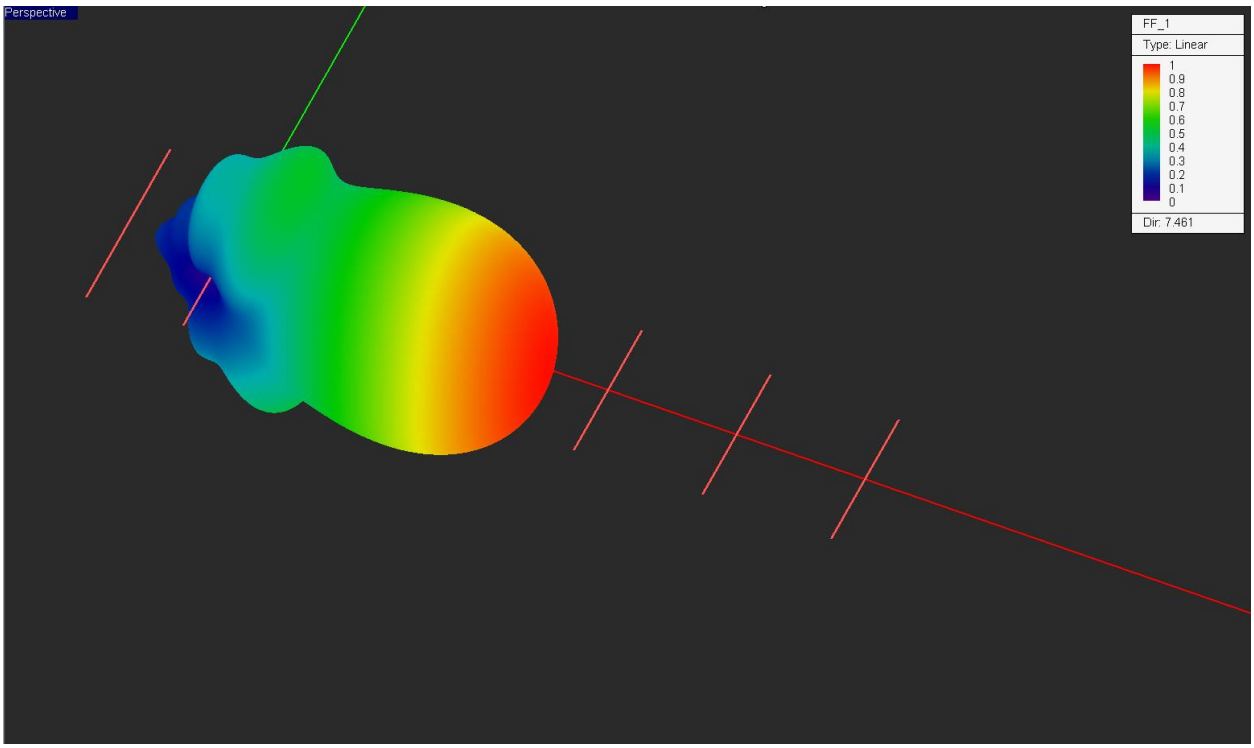


Figure 13. *The 3D far-field radiation pattern of the Yagi-Uda antenna array with 5 directors.*

Next, open the Data Manager and plot the data files "FF_1_PATTERN_Polar_XY.ANG" and "FF_1_PATTERN_Polar_ZX.ANG" as shown in the figures 14 and 15. These are the polar graphs of the radiation patterns at the principal XY and ZX planes, respectively.

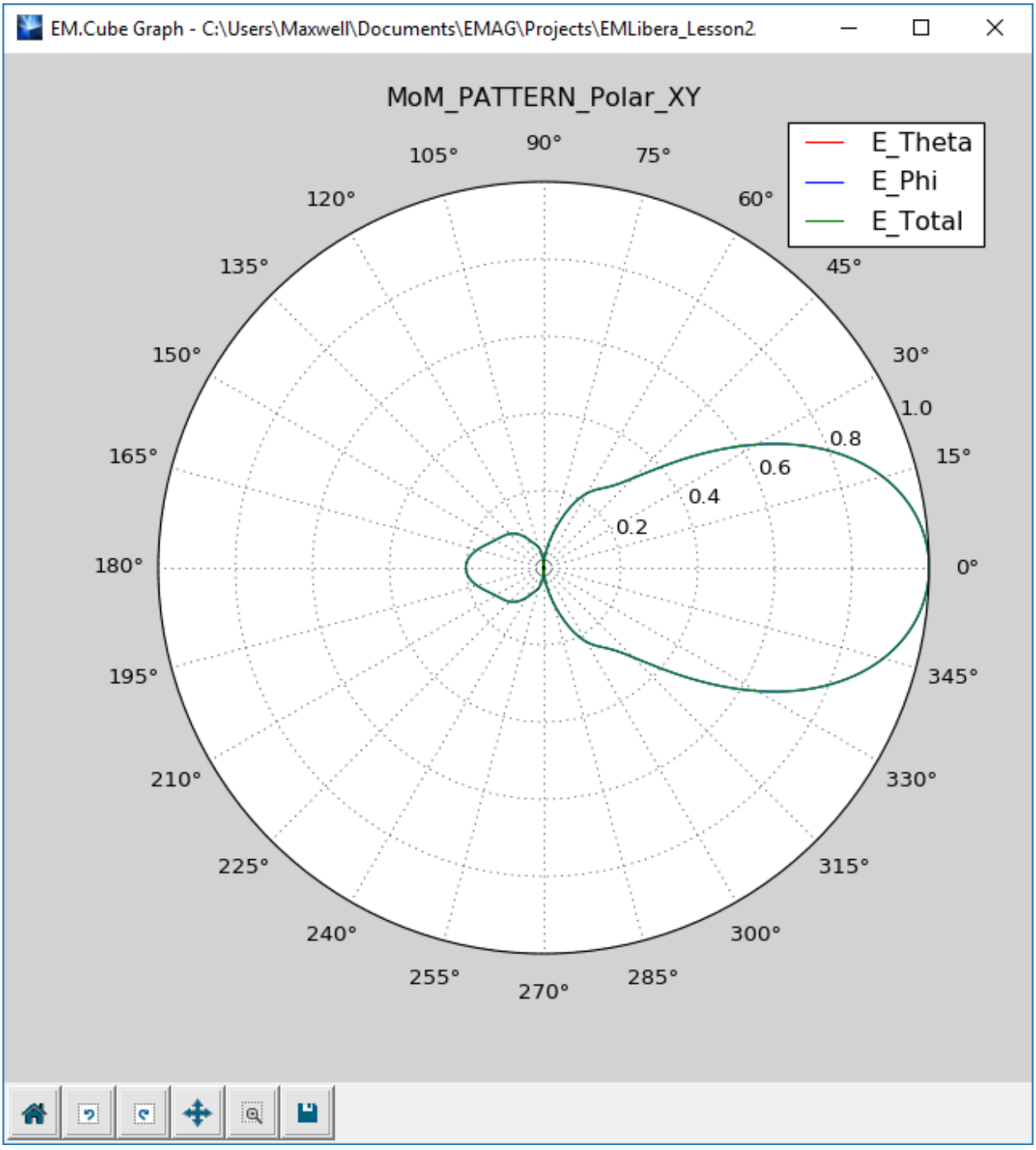


Figure 14. *The 2D polar XY-plane radiation pattern of the Yagi-Uda antenna array with 5 directors.*

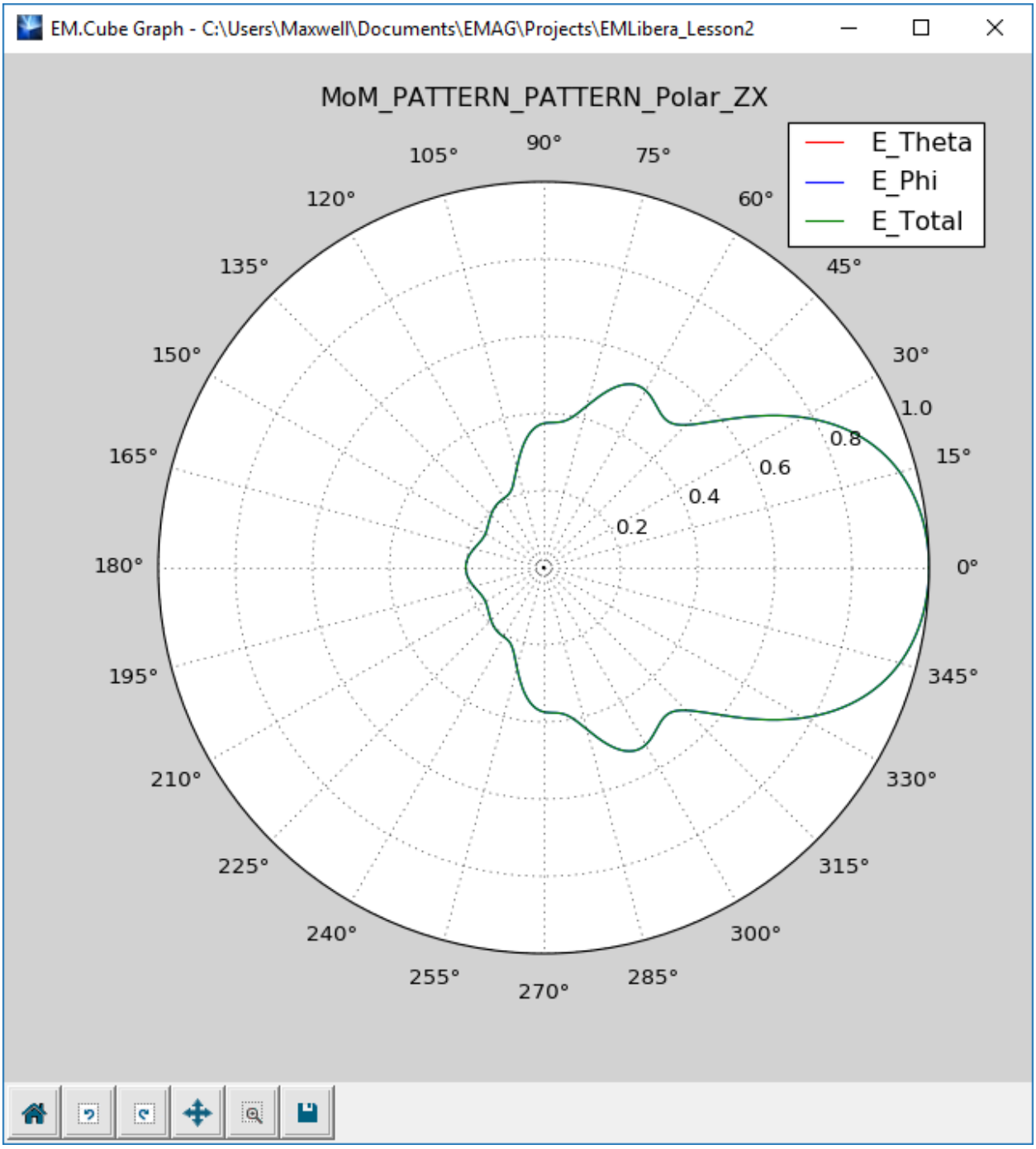


Figure 15. *The 2D polar ZX-plane radiation pattern of the Yagi-Uda antenna array with 5 directors.*

You can also view the contents of any data file in the data manager by selecting its name and clicking the **View** button of this dialog. The table below shows some of the computed radiation characteristics of your Yagi-Uda array.

Data File Name	Radiation Characteristic	Value
HPBW_XY.DAT	Half power beam width in XY palne	53.86°
HPBW_ZX.DAT	Half power beam width in ZX palne	67.77°

2.7 Running a Parametric Sweep of the Number of Director Elements

In the last part of this tutorial lesson, you are going to increase the number of director elements and see its effect on the array characteristics. In a sweep simulation, one or more parameters are varied, and the simulation engine is run for each parameter set. Open the Run Simulation dialog and choose the **Parametric Sweep** option from the **Simulation Mode** drop-down list (Figure 16). Click on the **Settings** button next to this drop-down list to open the Parametric Sweep Settings dialog. You will notice a red box next to the drop-down list. This means that you are not ready to run a simulation because some parameters have not been set yet.

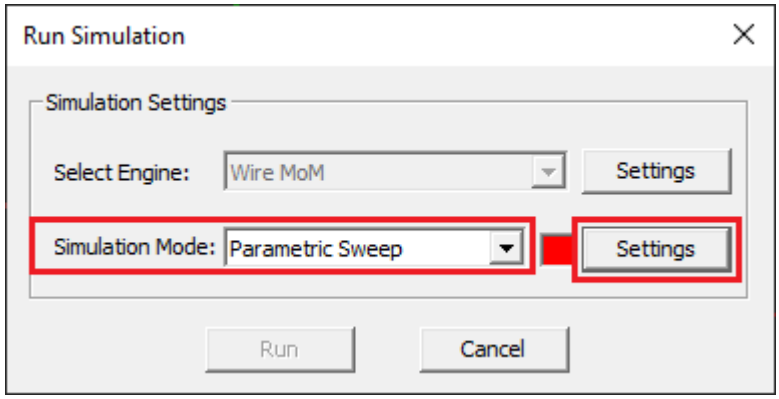


Figure 16. *Selecting parametric sweep as the simulation mode in EM.Libera's run dialog.*

In the Parametric Sweep Settings dialog, the **Sweep Variables** list is initially empty (Figure 17). On the left side of this dialog, you see a list of all the available **Independent Variables**. Note that out of all the array-related variables you saw earlier in the variables dialog, only one called "n_direct" is listed here. This is the number of director elements in the Yagi-Uda array, and it is an independent variable. All the other array-related variables such as wire lengths, spacings, etc. are dependent variables whose definitions involve another variable called "lambda0_unit", the operating wavelength.

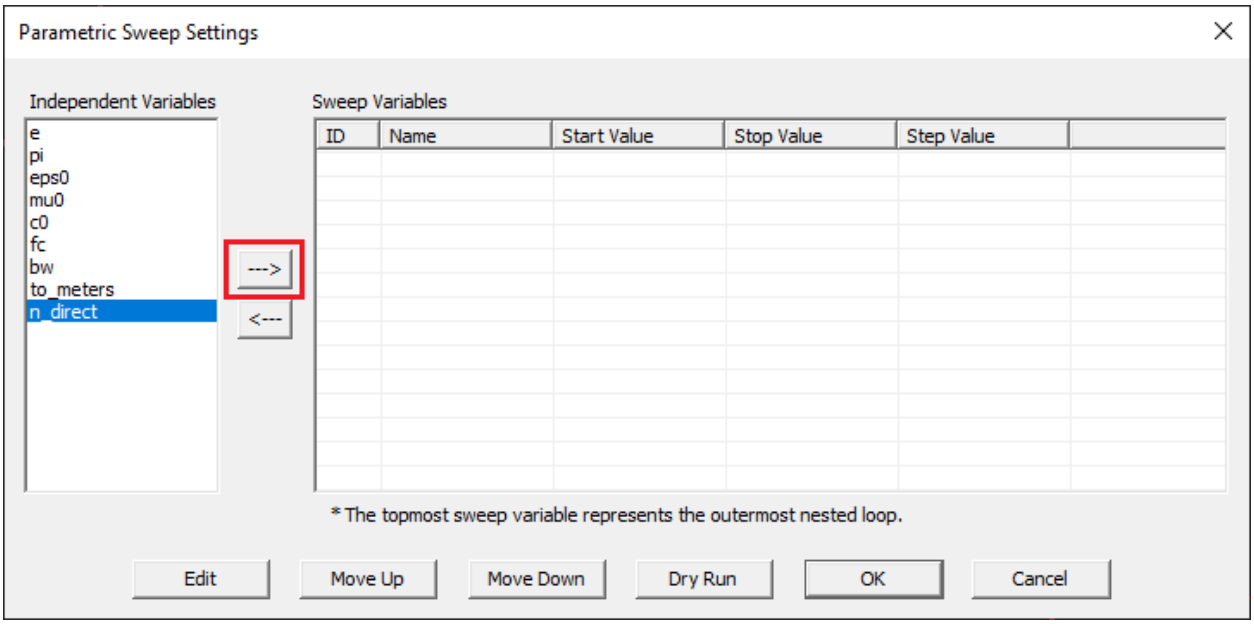


Figure 17. *Parametric sweep settings dialog before designating a sweep variable.*

Select and highlight "n_direct" from the left table and use the right arrow 

button to move it to the right table. Another dialog titled Define Sweep Variable opens up (Figure 18). You have to set the **Start Value**, **Stop Value** and **Step Values** of your sweep variable. By default, the sweep variable is of uniform type. Enter 5, 13, and 1 for the **Start Value**, **Stop Value** and **Step Value**, respectively. This will create a value list of {5, 6, 7, 8, 9, 10, 11, 12, 13}.

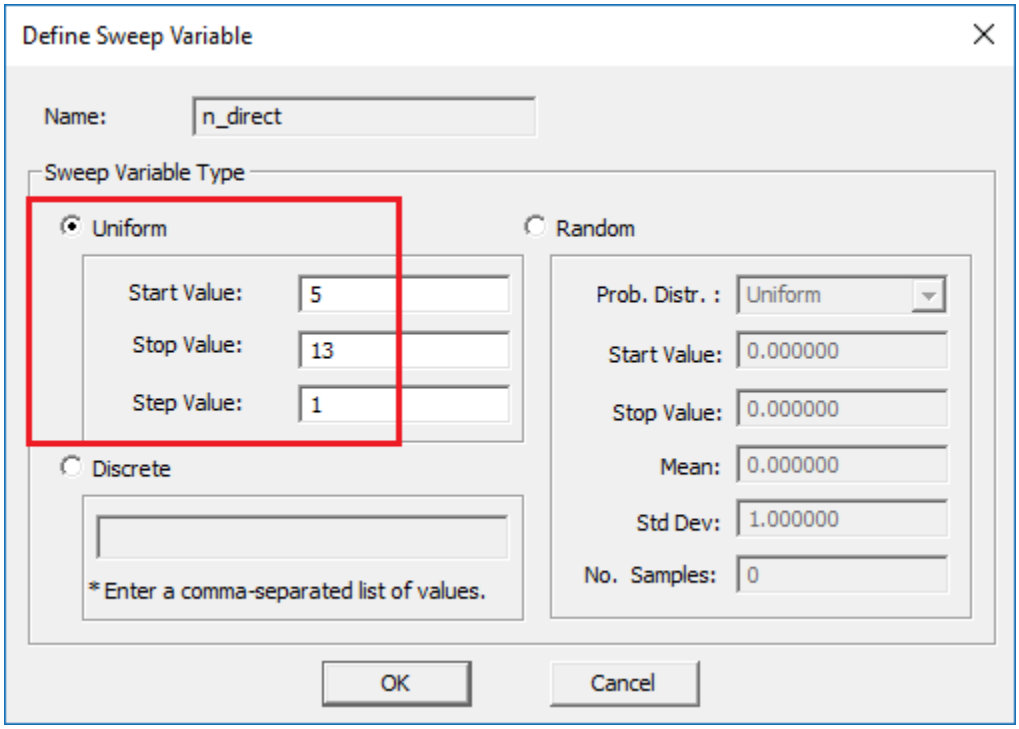


Figure 18. *Sweep Variable Settings dialog.*

Click the **OK** button to close the Define Sweep Variable dialog and return to the Parametric Sweep Settings dialog (Figure 19).

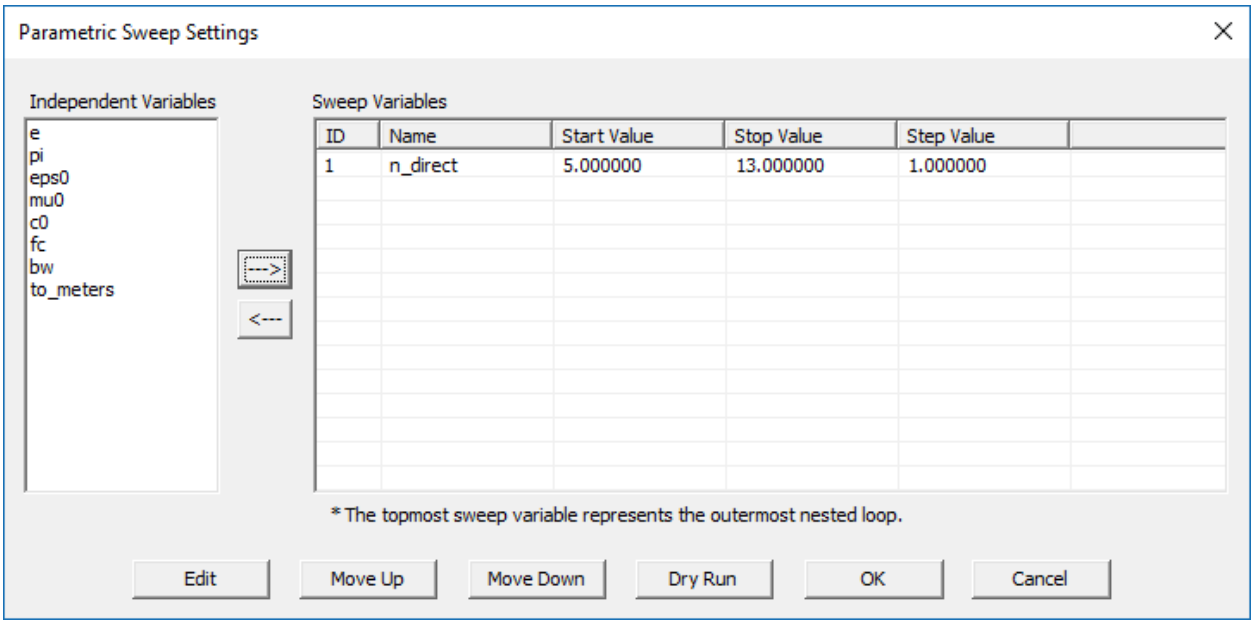


Figure 19. *Parametric Sweep Settings dialog after designating "n_direct" as the sweep variable.*

Then click the **OK** button to close the Parametric Sweep Settings dialog and return to the Run Simulation dialog. Run the sweep simulation. It may take a while as a total of nine individual WMOM simulations must be completed. At the end of the parametric sweep, you will see a total of nine 3D radiation pattern plots in the navigation tree. Figures 20-22 shows some of these plots.

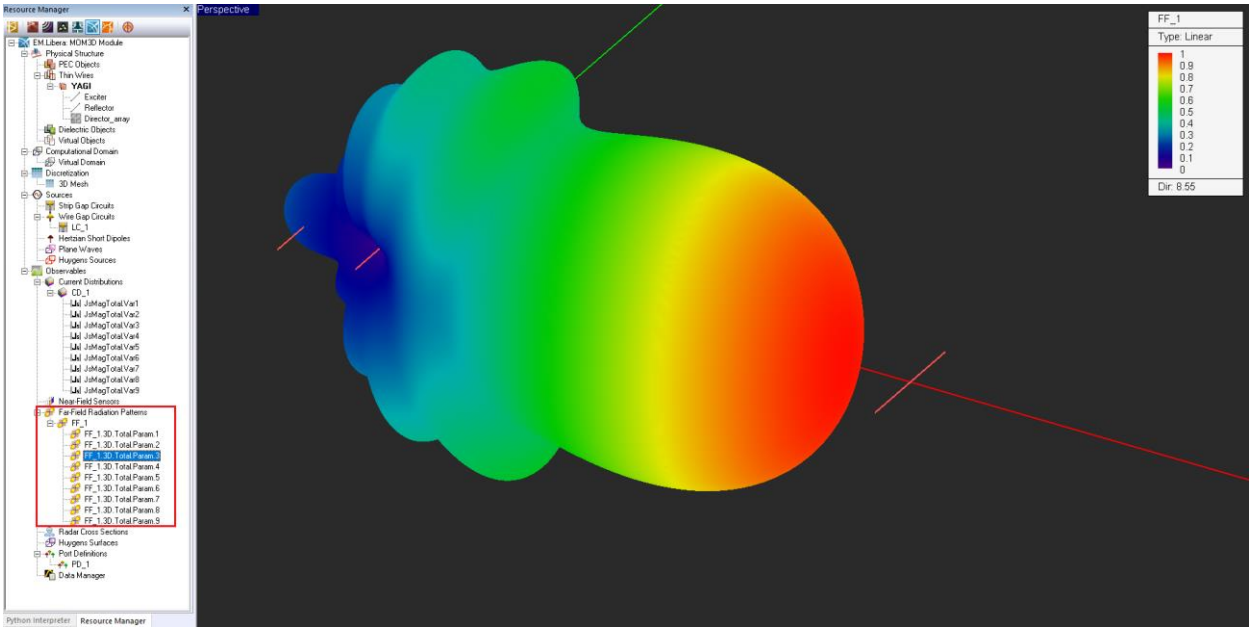


Figure 20. *The 3D Radiation Pattern of the Yagi-Uda array with 7 directors.*

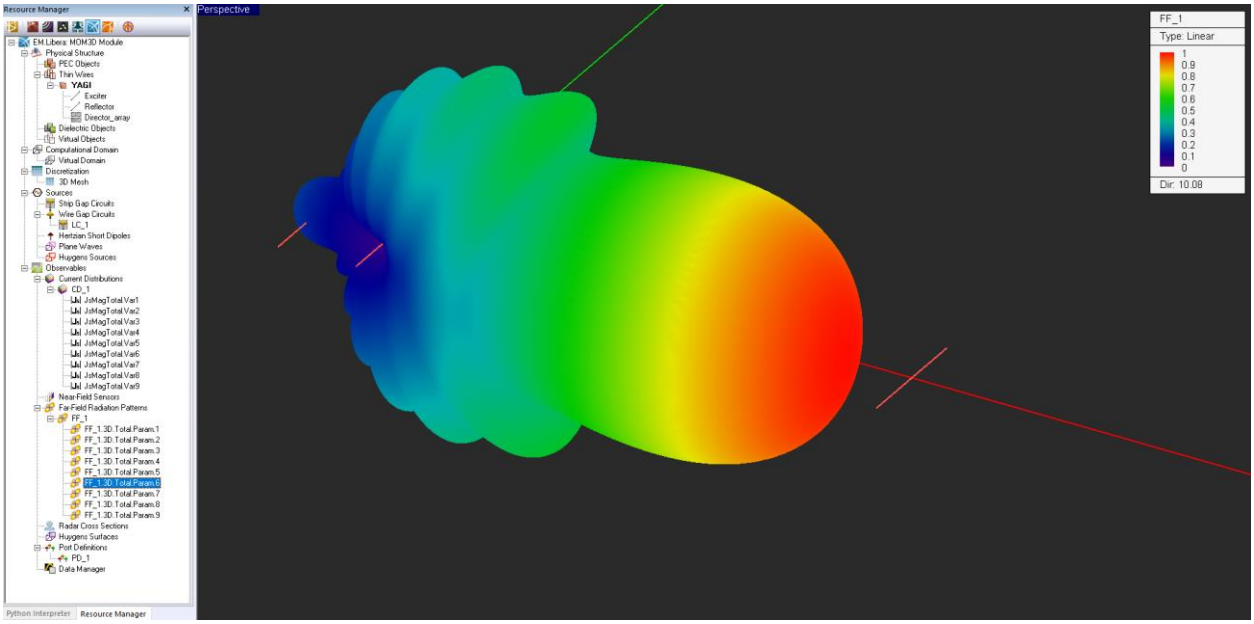


Figure 21. *The 3D Radiation Pattern of the Yagi-Uda array with 10 directors.*

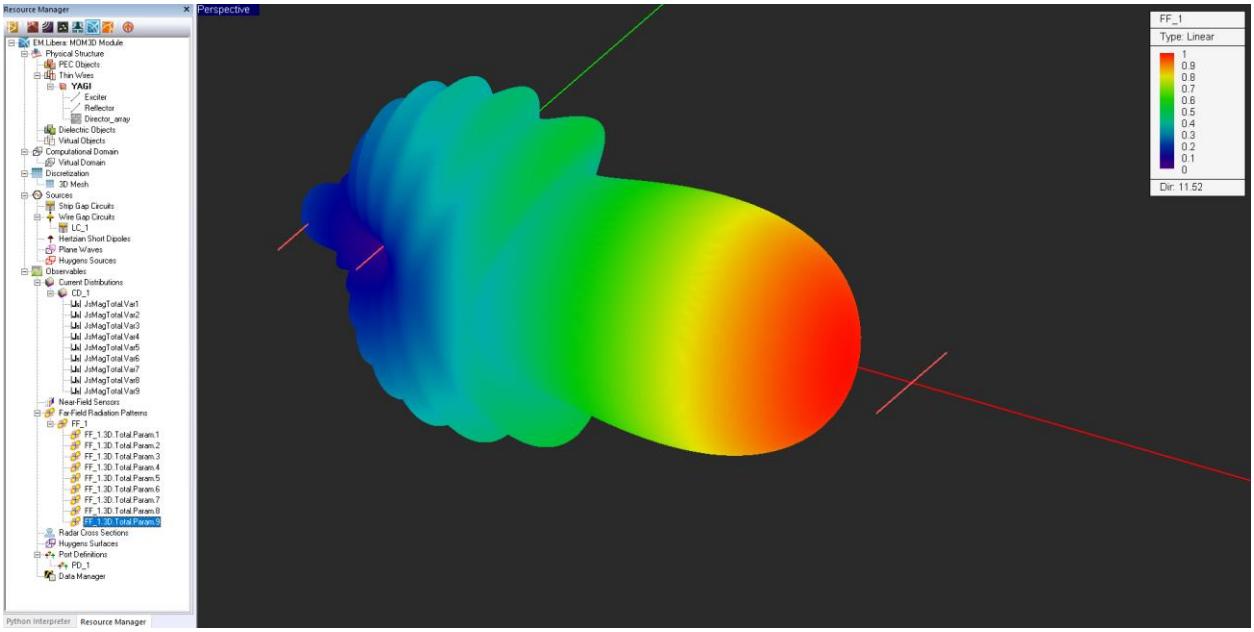


Figure 22. *The 3D Radiation Pattern of the Yagi-Uda array with 13 directors.*

2.8 Analyzing the Array Directivity Data

Open the Data Manager and plot the data file "FF_D0_Sweep.DAT". You should see a graph like Figure 23 as shown below. It shows the variation of the directivity (D0) of the array as a function of the number of director elements. An almost linear variation is observed.

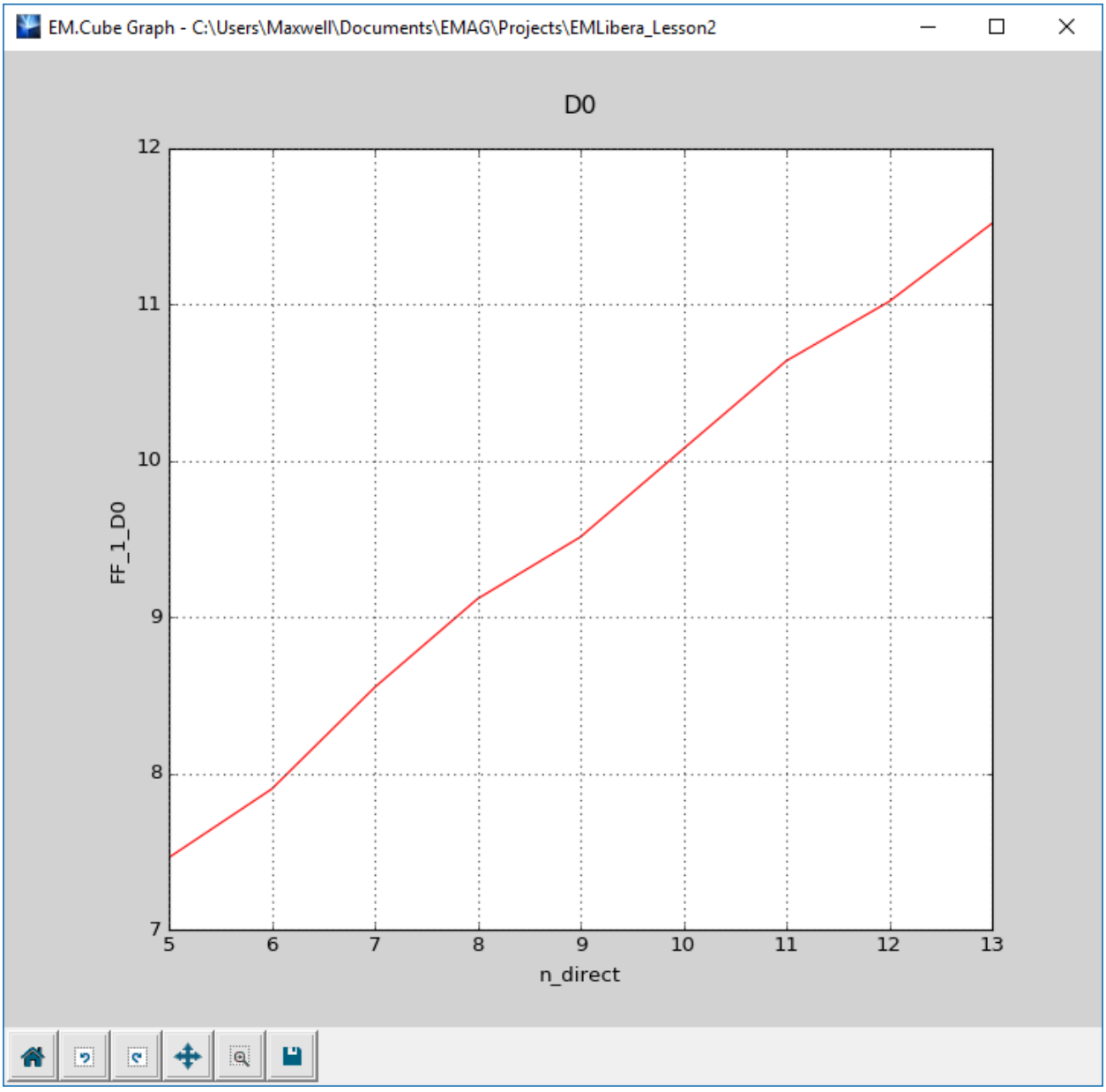
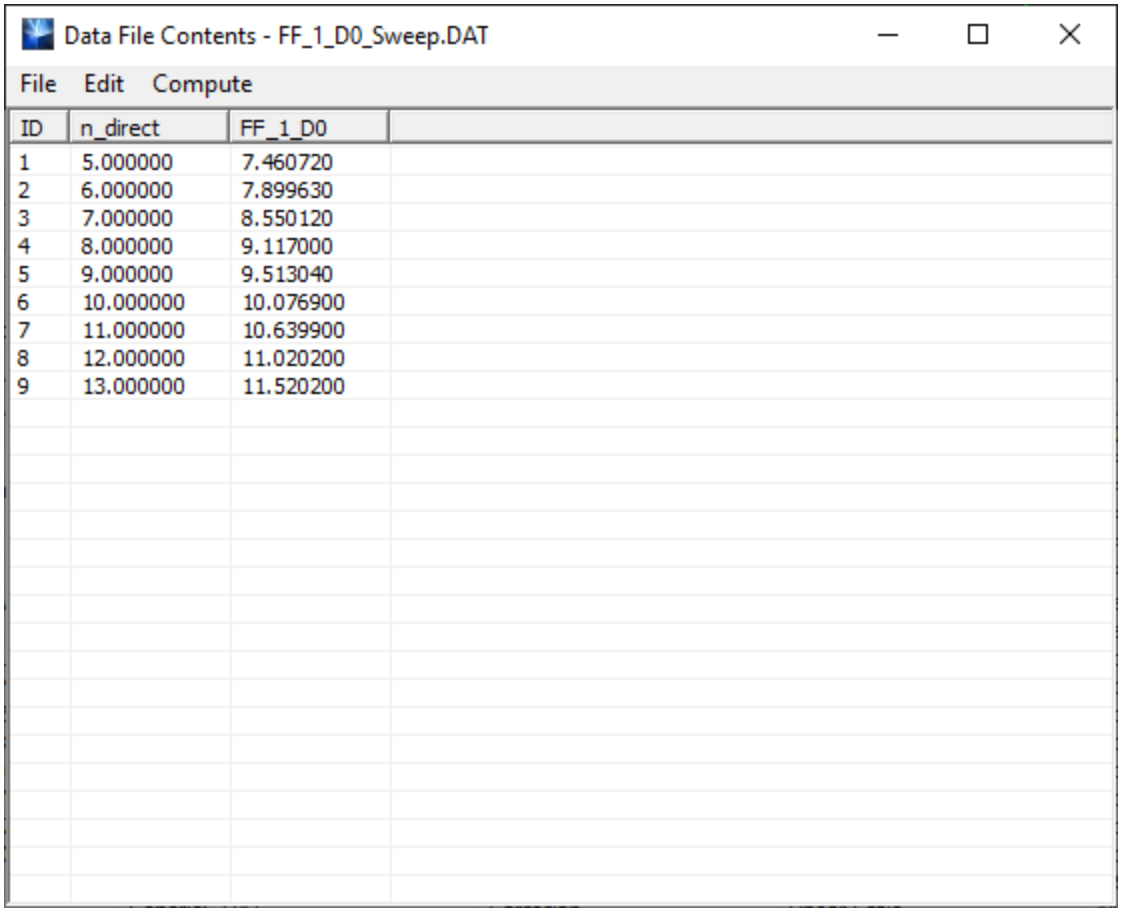


Figure 22. *The graph of variation of the directivity of the Yagi-Uda array as a function of number of directors.*

Next, while still in the Data Manager, view the contents of the data file "FF_D0_Sweep.DAT" in a spreadsheet using the **View** button of this dialog (Figure 24).



ID	n_direct	FF_1_D0
1	5.000000	7.460720
2	6.000000	7.899630
3	7.000000	8.550120
4	8.000000	9.117000
5	9.000000	9.513040
6	10.000000	10.076900
7	11.000000	10.639900
8	12.000000	11.020200
9	13.000000	11.520200

Figure 24. *The data manager spreadsheet showing the directivity data.*