E

EMCUBE®

PLANAR.MODULE

# EM.Picasso

# Tutorial Lessons

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# EM.Picasso Tutorial Lesson 8

## Analyzing a CPW-Fed Folded Dipole Slot Antenna

# Table of Contents

## 8.1 What You Will Learn

In this tutorial you will learn how to construct and simulate slot structures. You will define coupled ports to model coplanar waveguide (CPW) structures.

**EM.Picasso Manual:**

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

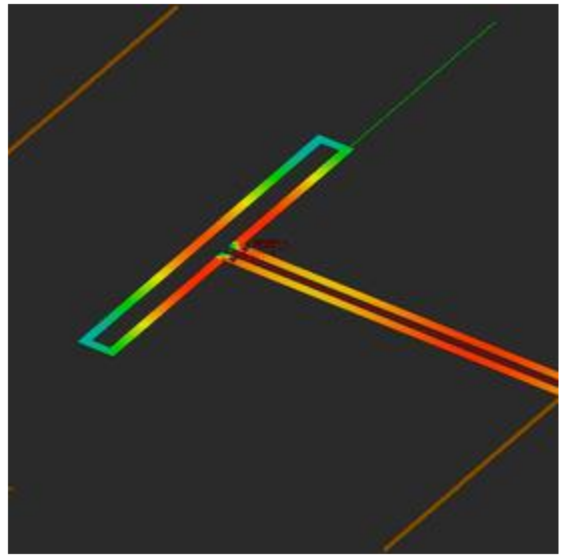
**EM.Picasso Tutorial Gateway:**

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

**Download projects related to this tutorial lesson:**

http://www.emagtech.com/downloads/ProjectRepo/EMPicasso_Lesson8.zip

**Tutorial Project: Analyzing A CPW-Fed Folded Dipole Slot Antenna**



**Objective:** In this project, you will build a slot-based planar structure and excite it using a pair of coupled scattering wave ports.

**Concepts/Features:**

- CubeCAD
- Slot Trace
- Coplanar Waveguide
- De-embedded Source
- Port Definition
- Coupled Ports
- Radiation Pattern
- Adaptive Sweep

**Minimum Version Required:** All versions

## 8.2 Getting Started

Start a new project with the following parameters:

| Starting Parameters | |
|---|---|
| **Name** | EMPicasso_Lesson8 |
| **Length Units** | Millimeters |
| **Frequency Units** | GHz |
| **Center Frequency** | 1.7GHz |
| **Bandwidth** | 0.6GHz |

| Substrate Configuration | |
|---|---|
| **Number of Finite Layers** | 1 |
| **Top Half-Space** | Vacuum |
| **Top Layer** | $\varepsilon_r = 2.2, \sigma = \sigma_m = 0$, Thickness = 1.2mm |
| **Bottom Half-Space** | Vacuum |

## 8.3 Creating the Base One-Port Coplanar Waveguide Line

Click on the **CPW Wizard**  button of the **Wizard Toolbar** (Figure 1) or select the menu item **Tools** → **Transmission Line Wizards** → **Coplanar Waveguide**.

***Figure 1.*** *EM.Picasso's Wizard Toolbar.*

Open the variables dialog and change the definition of the following variables:

| Variable Name | Original Definition | New Definition |
|---|---|---|
| h | 0.0015*to_meters | 1.2 |
| feed_len | 0.5*center_len | 30 |

The wizard creates the geometry of a one-port coplanar waveguide in the project workspace (Figure 2). The default coplanar waveguide structure is made up of four rectangle strip objects grouped under a slot trace called "CPW":

1. ANCHOR
2. Slot_2
3. Feed_1
4. Feed_2

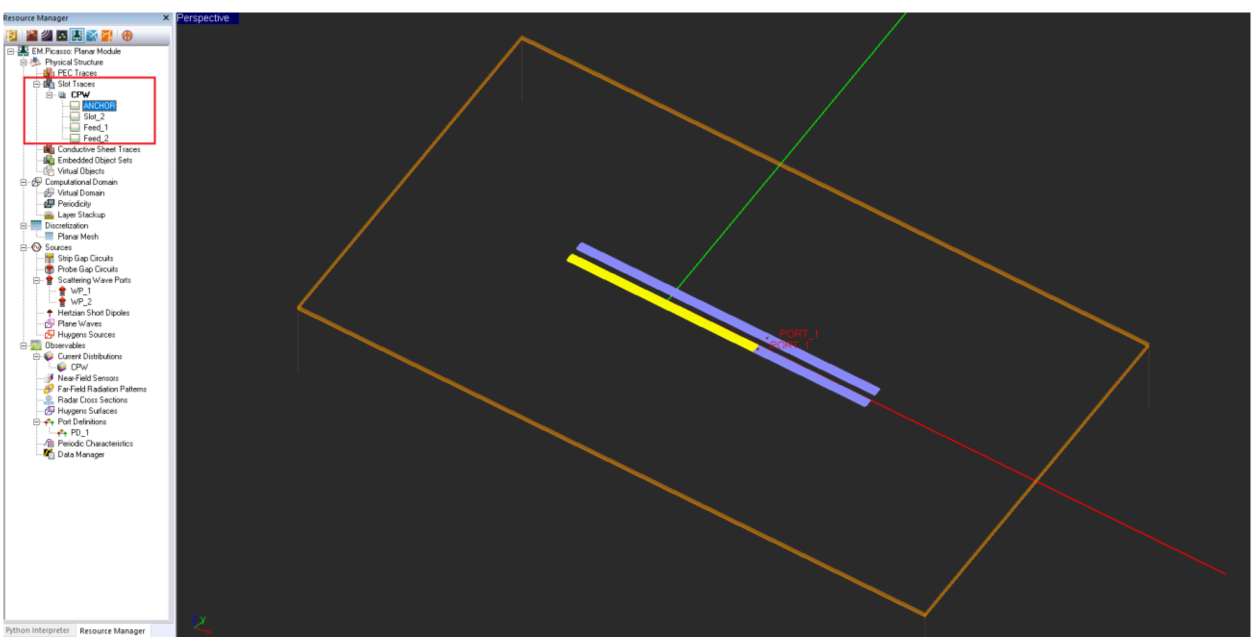



***Figure 2.*** *The geometry of the one-port CPW line created by the wizard in the project workspace. The anchor object is selected and highlighted in yellow.*

The objects wizards created are not only highly parameterized, but they are also usually linked to one another. This means that you can move them or rotate them together without affecting their parameterization. But they are rules to follow. The object named "ANCHOR" is the one which you should translate or rotate. Most other objects initially created by a wizard are linked to the anchor and follow its translation or rotation.

As you saw in the previous tutorial lesson, slot structures in EM.Picasso are modeled as magnetic currents on an infinite ground plane. The slot trace "CPW" is sandwiched between the finite dielectric layer and the top half-space. Open EM.Picasso's Stackup Settings dialog to see the substrate layer hierarchy (Figure 3).

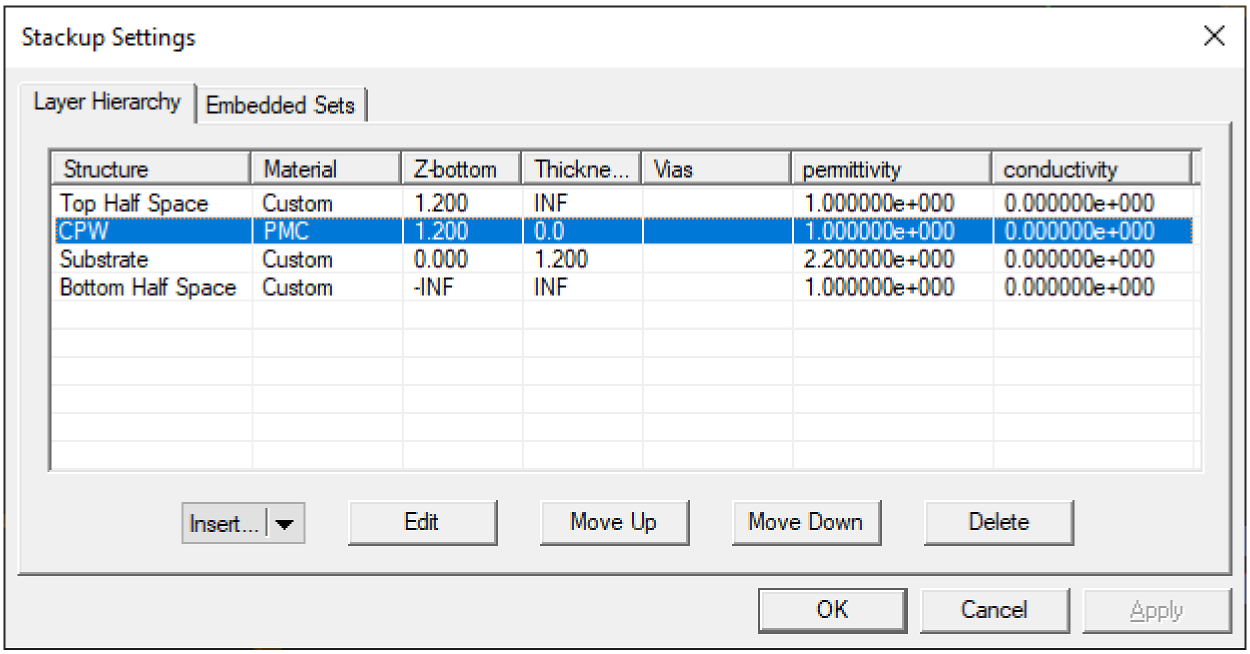



***Figure 3.*** *EM.Picasso's Stackup Settings dialog showing the slot trace.*

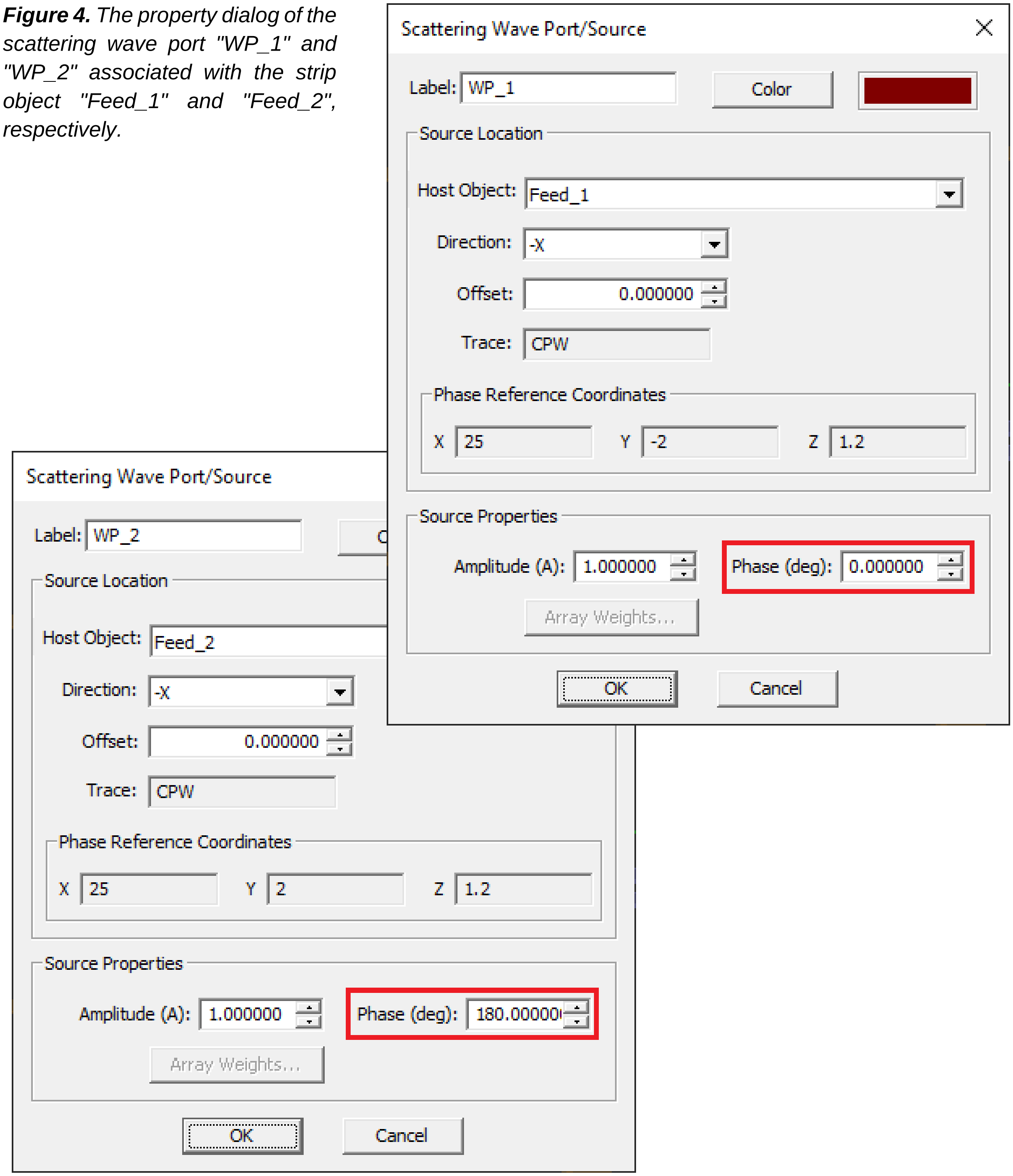
Keep in mind that the default setting of the bottom half-space is PEC when you create a new project. When working with slot structures, make sure that the bottom half-space material is set to vacuum to represent the free space.

⚠ Slot traces are assumed to lie on an infinite, horizontal, PEC ground plane. The finite objects belonging to a slot trace group represent cut-out parts off this ground plane. Metal and slot trace groups cannot be collocated on the same Z-plane.

## 8.4 Examining the Coupled Sources & Port Definition

The wizard created two scattering wave port sources called "WP_1" and "WP2". Open the property dialog of both sources and inspect their properties (Figure 4). You will notice that the two sources are out of phase. They have been set to have a phase difference of 180° to excite coplanar waveguide's dominant odd mode.

***Figure 4.*** *The property dialog of the scattering wave port "WP_1" and "WP_2" associated with the strip object "Feed_1" and "Feed_2", respectively.*




The wizard also initiated a Port Definition for the two wave port sources. If you open the Port Definition dialog, you will notice that there is only one port in the list rather than two (Figure 5). The only define port called "Port_1" has been associated with both sources "WP_1" and "WP_2". In other words, the two sources have been coupled to each other, creating a single port. Select and highlight "Port_1" in the table and click the **Add** button of the dialog. This opens the "Add Port" dialog from which you can modify the source associations (Figure 6). Close the dialogs and return to the project workspace.

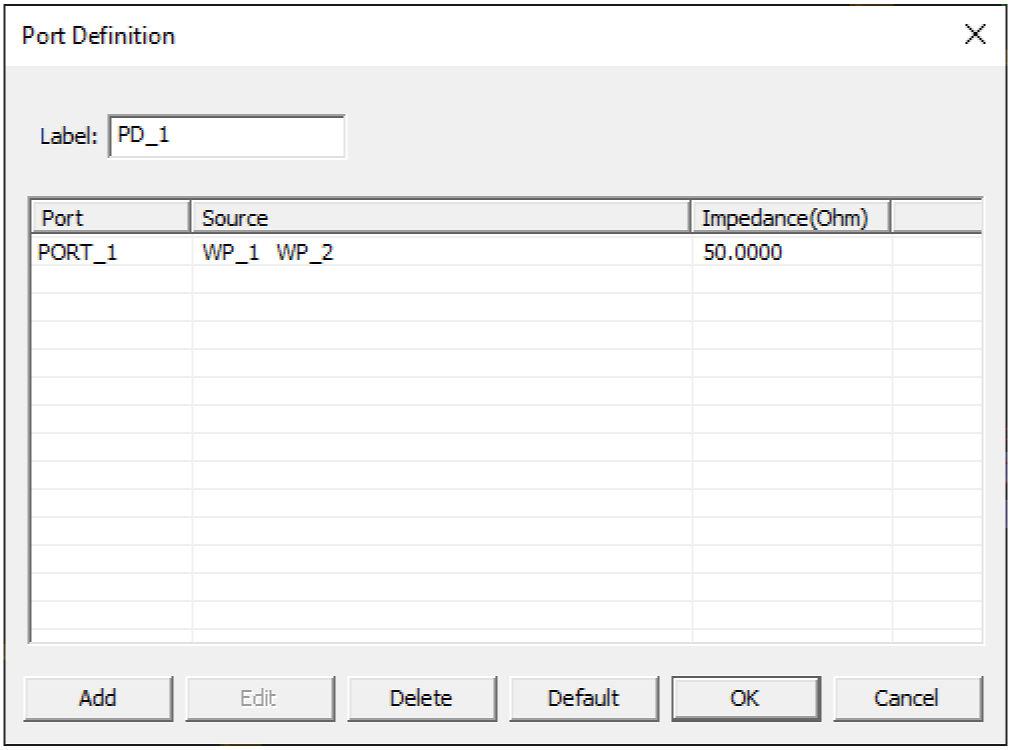



***Figure 5.*** *The Port Definition dialog showing two coupled sources.*

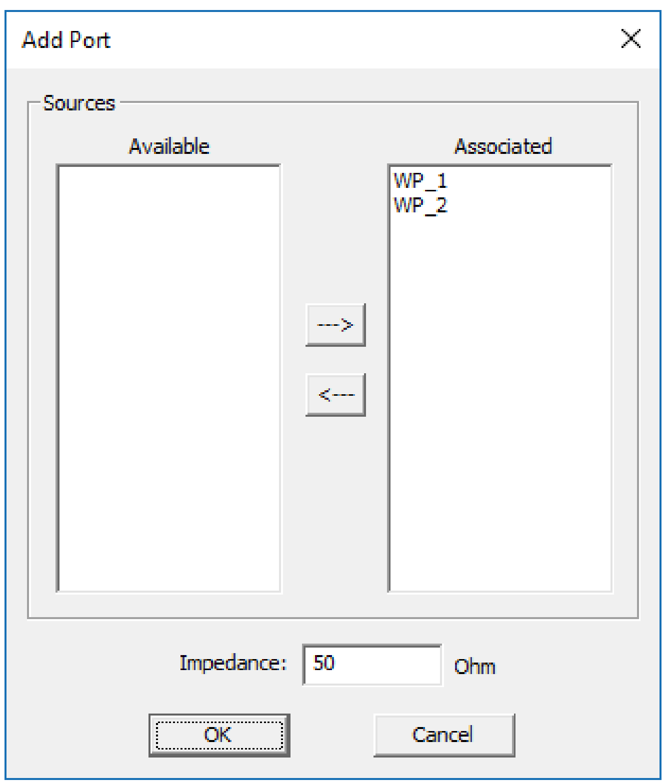
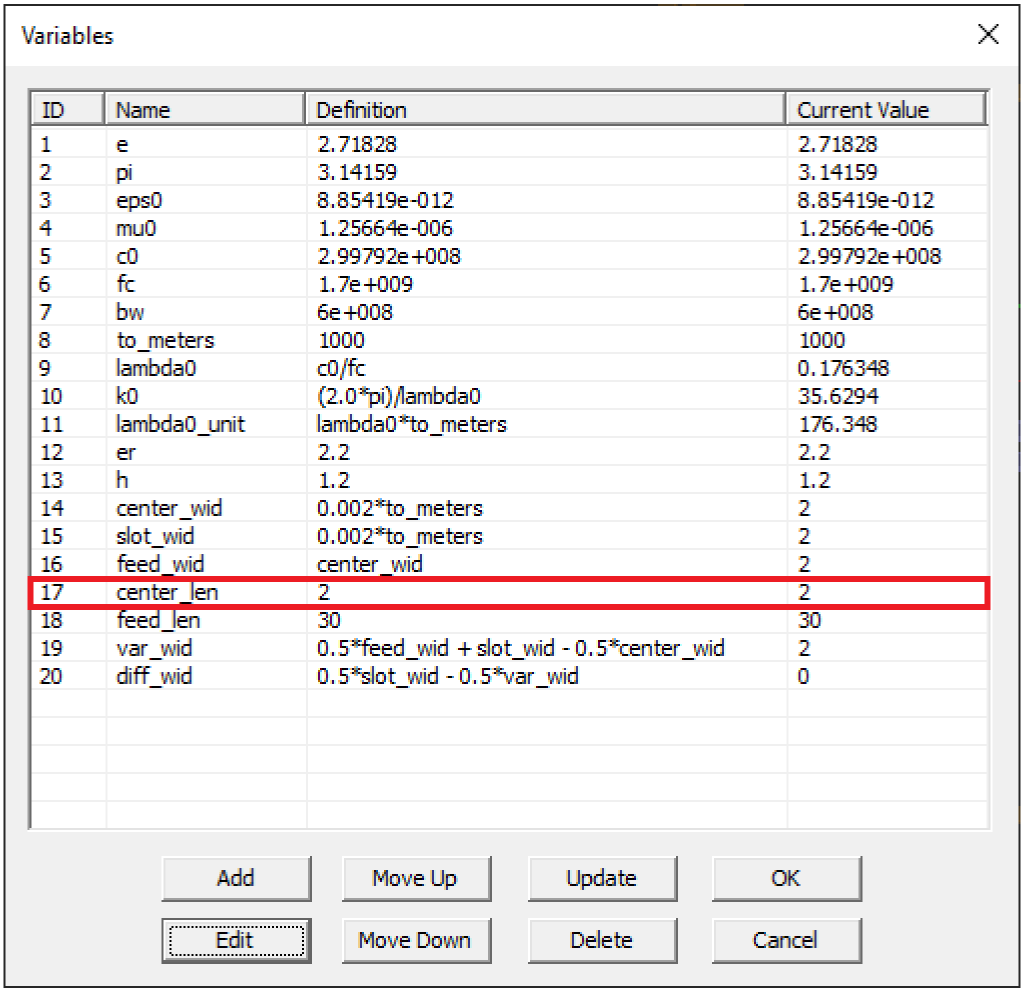



***Figure 6.*** *The Add Port dialog.*

## 8.5 Drawing the Additional Slot Segments

Open the Variables dialog again and change the definition of variable "center_len" to 2 as shown in Figure 7. This will turn the objects "ANCHOR" and "Slot_2" into small joint squares.



| ID | Name | Definition | Current Value |
|---|---|---|---|
| 1 | e | 2.71828 | 2.71828 |
| 2 | pi | 3.14159 | 3.14159 |
| 3 | eps0 | 8.85419e-012 | 8.85419e-012 |
| 4 | mu0 | 1.25664e-006 | 1.25664e-006 |
| 5 | c0 | 2.99792e+008 | 2.99792e+008 |
| 6 | fc | 1.7e+009 | 1.7e+009 |
| 7 | bw | 6e+008 | 6e+008 |
| 8 | to_meters | 1000 | 1000 |
| 9 | lambda0 | c0/fc | 0.176348 |
| 10 | k0 | (2.0*pi)/lambda0 | 35.6294 |
| 11 | lambda0_unit | lambda0*to_meters | 176.348 |
| 12 | er | 2.2 | 2.2 |
| 13 | h | 1.2 | 1.2 |
| 14 | center_wid | 0.002*to_meters | 2 |
| 15 | slot_wid | 0.002*to_meters | 2 |
| 16 | feed_wid | center_wid | 2 |
| 17 | center_len | 2 | 2 |
| 18 | feed_len | 30 | 30 |
| 19 | var_wid | 0.5*feed_wid + slot_wid - 0.5*center_wid | 2 |
| 20 | diff_wid | 0.5*slot_wid - 0.5*var_wid | 0 |



***Figure 7.*** *The variables list showing the modified definition of the variable "center_len".*

Next, draw the following five rectangle strip objects in the project workspace:

| Label | Object Type | LCS Origin | Length | Width |
|---|---|---|---|---|
| Rect1 | Rectangle Strip | (0, -20mm, 1.2mm) | 2mm | 34mm |
| Rect2 | Rectangle Strip | (0, 20mm, 1.2mm) | 2mm | 34mm |
| Rect3 | Rectangle Strip | (-6mm, 0, 1.2mm) | 2mm | 74mm |
| Rect4 | Rectangle Strip | (-3mm, -38mm, 1.2mm) | 8mm | 2mm |
| Rect5 | Rectangle Strip | (-3mm, 38mm, 1.2mm) | 8mm | 2mm |

After making all the changes and adding all the new slot segments, your physical structure should look like Figure 8.

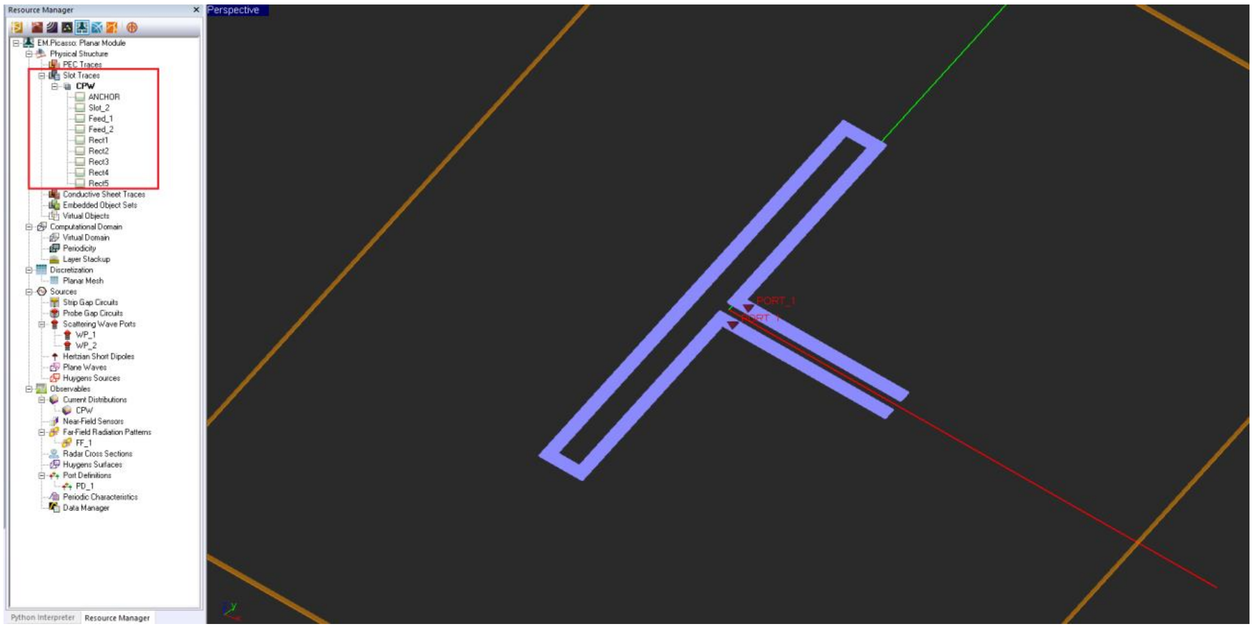



***Figure 8.*** *The geometry of the completed CPW-fed folded dipole slot antenna. The anchor object is selected and highlighted in yellow.*

## 8.6 Running a PMOM Analysis of the Slot Antenna

Before running the simulation, let's take a look at the planar mesh of your slot antenna (Figure 9). The wizard set **Mesh Density** for this structure to 40 cells/$\lambda_{\text{eff}}$.

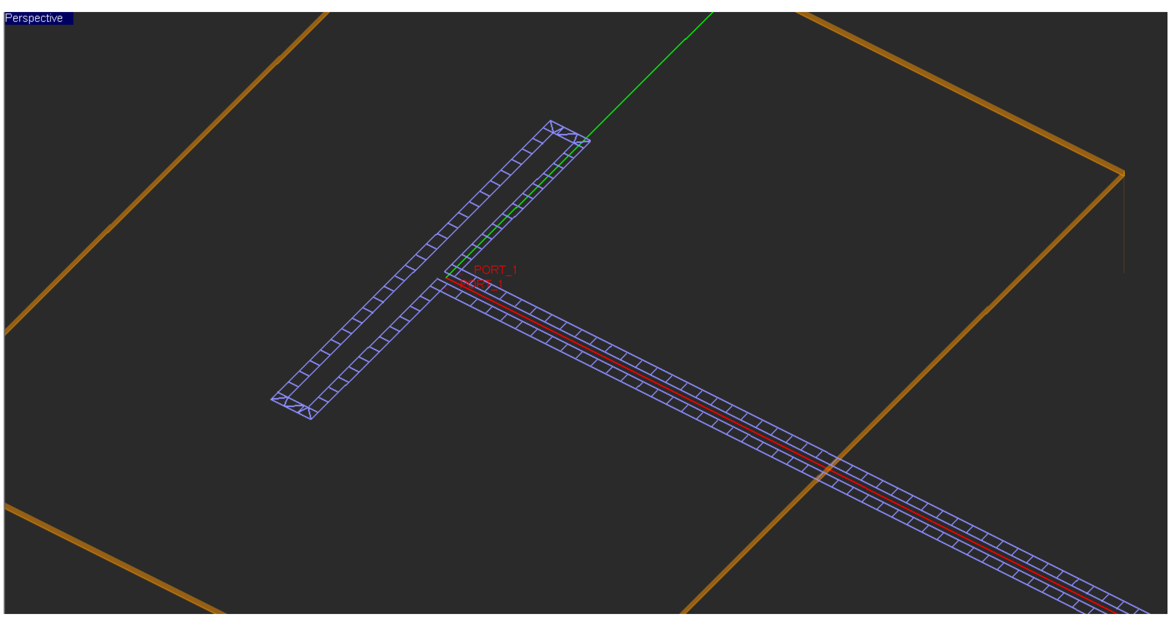



***Figure 9.*** *The planar mesh of the slot antenna.*

It is recommended that you use a higher mesh density for slot traces (PMC) compared to PEC traces. As you would expect, EM.Picasso extends both feed lines with scattering wave ports on them to $2\lambda_g$ in the mesh view. For a coplanar waveguide transmission line, $\lambda_{\text{eff}} = \lambda_0/\sqrt{\varepsilon_{\text{eff}}}$, where $\varepsilon_{\text{eff}} \approx (\varepsilon_r + 1)/2$ when the medium above the slot is vacuum and the one beneath it is a dielectric of permittivity $\varepsilon_r$.

Define a far-field radiation pattern observable and set both the theta and phi angle increments to 1° in the radiation pattern dialog.

Run a quick single-frequency PMOM analysis of your folded slot antenna. The port characteristics are reported as:

**S11: -0.019578 -0.075183j**

**S11(dB): -22.192665**

**Z11: 47.549339 -7.193173j**

**Y11: 0.020560 +0.003110j**

Keep in mind that since EM.Picasso models slot traces as perfect magnetic conductors (PMC), the electric surface current distribution is zero everywhere. Therefore, under the **Current Distributions** node "CPW" in the navigation tree, you should look at the magnetic current distribution plots instead (Figure 10). Note that the magnetic current density has units of V/m, which is the same as that of electric field.

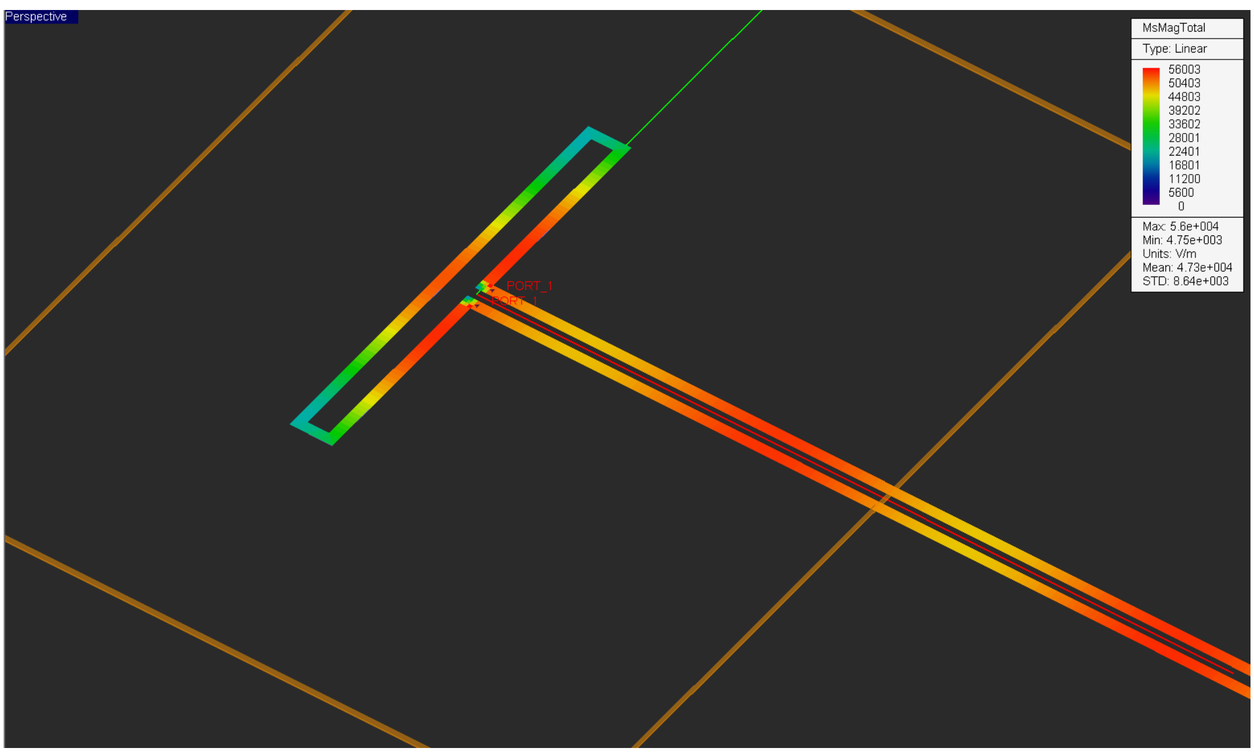



***Figure 10.*** *The total magnetic current distribution plot of the slot antenna ("MsMagTotal").*

Visualize the 3D radiation pattern of the slot antenna (Figure 11). The radiation pattern is typical of a dipole antenna as you would expect. The discontinuity at $\theta = 90°$, is due to the presence of the infinite dielectric substrate layer.

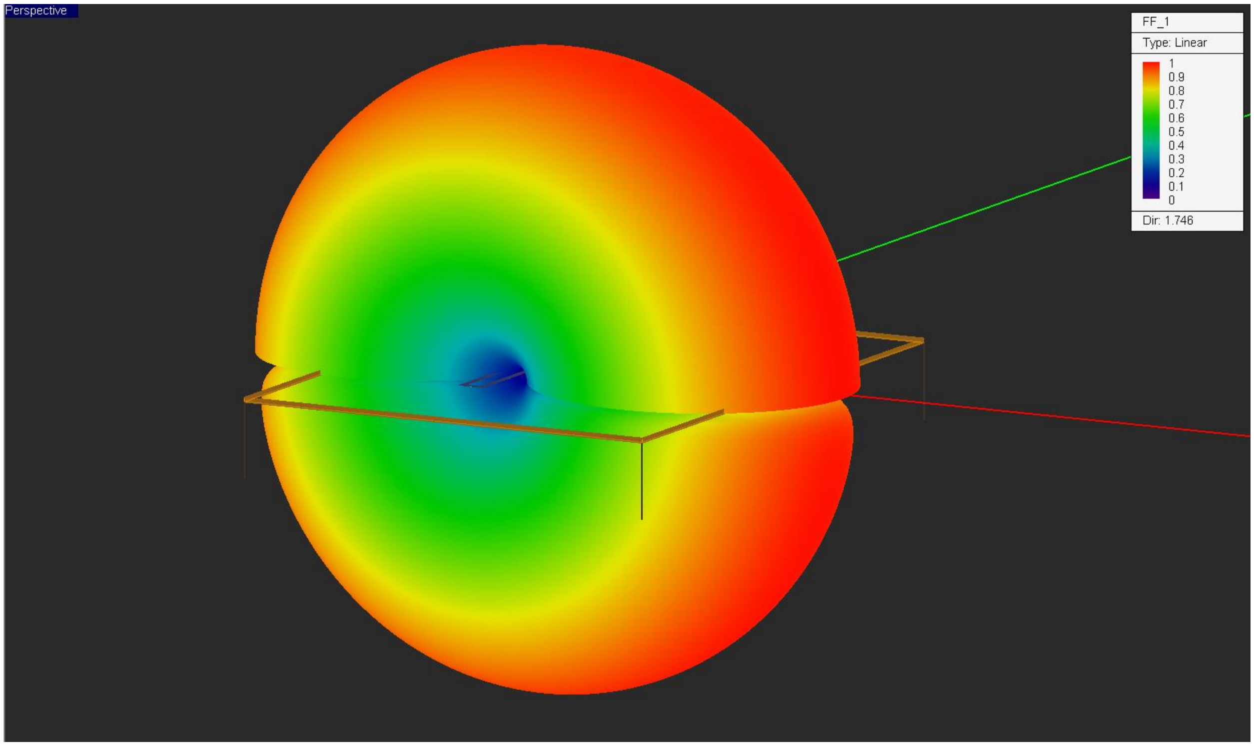



***Figure 11.*** *The 3D radiation pattern of the slot antenna.*

## 8.7 Examining the Resonant Behavior of the Slot Antenna

Next, you will run a frequency sweep of your folded dipole slot antenna to examine its frequency response and resonant behavior. Run an adaptive frequency sweep of your physical structure with the following parameters:

| | |
|---|---|
| **Start Frequency** | 1.4GHz |
| **End Frequency** | 2GHz |
| **No. Samples** | 11 |
| **Fix Mesh at Center Frequency** | |

After the completion of the sweep simulation, perform a Smart Fit interpolation of the data files "S11_Sweep_.CPX" with **Interpolant Order** of 4. Keep the default to **Interpolate** for "All Available Parameters". Then graph three data files: "S11_Sweep_RationalFit.CPX", "Z11_Sweep_RationalFit.CPX" and "VSWR_Sweep_RationalFit.DAT". You will see that around 1.66GHz, the magnitude of $S_{11}$ (return loss) dips into a deep minimum representing a very good impedance match. Also note that the slot antenna features a 10-dB return loss bandwidth of more than 330MHz (Figure 12).

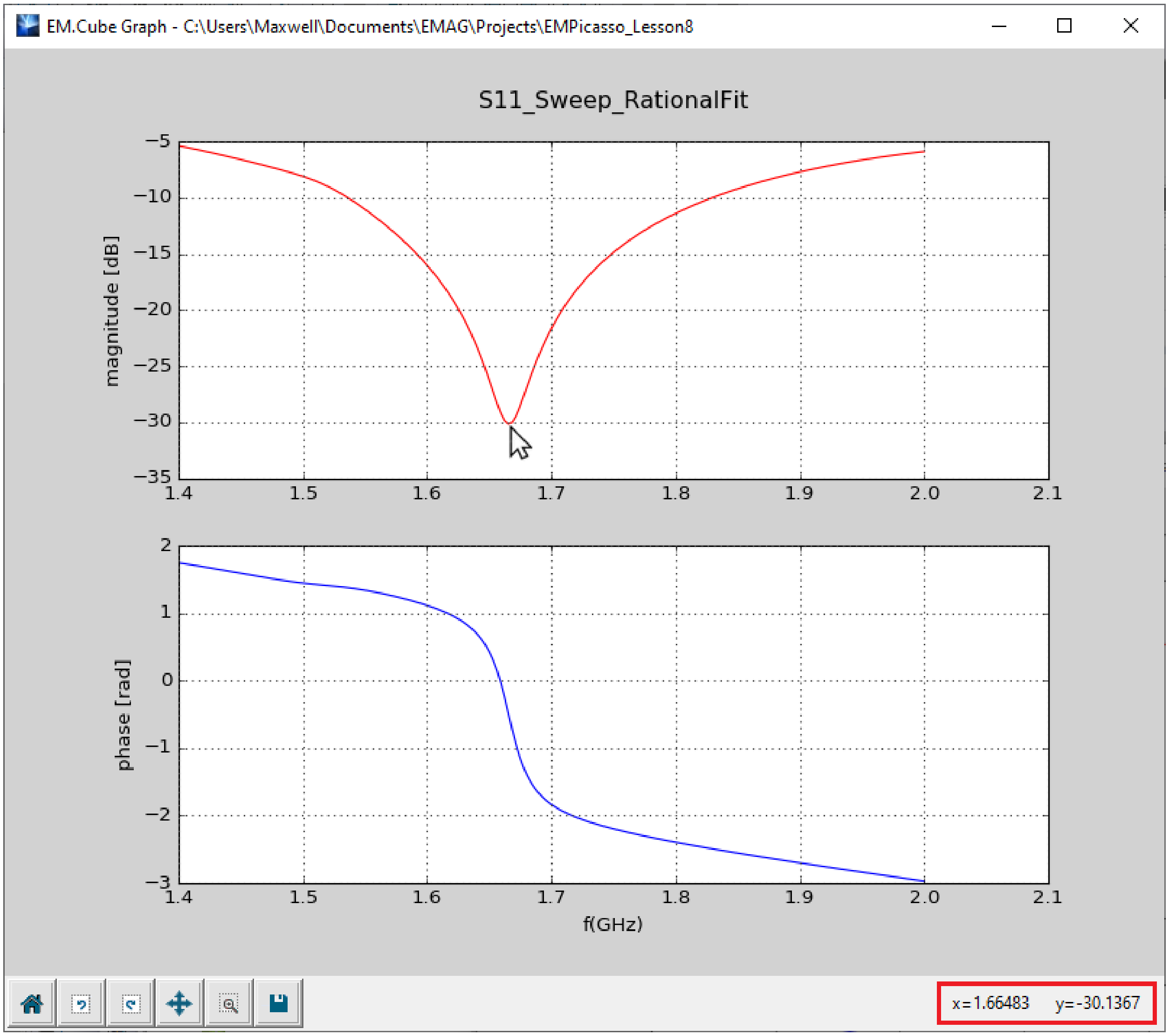



***Figure 12.*** *The graph of the $S_{11}$ parameter (return loss) of the folded slot antenna.*

Move the mouse on the $Z_{11}$ graph and read the value of the horizontal axis (frequency) and the corresponding value of the real and imaginary parts of $Z_{11}$-parameter in the settings panel. In Figure 13, you can see that around 1.66GHz, the imaginary part of $Z_{11}$ (i.e. input reactance) vanishes and the antenna resonates.

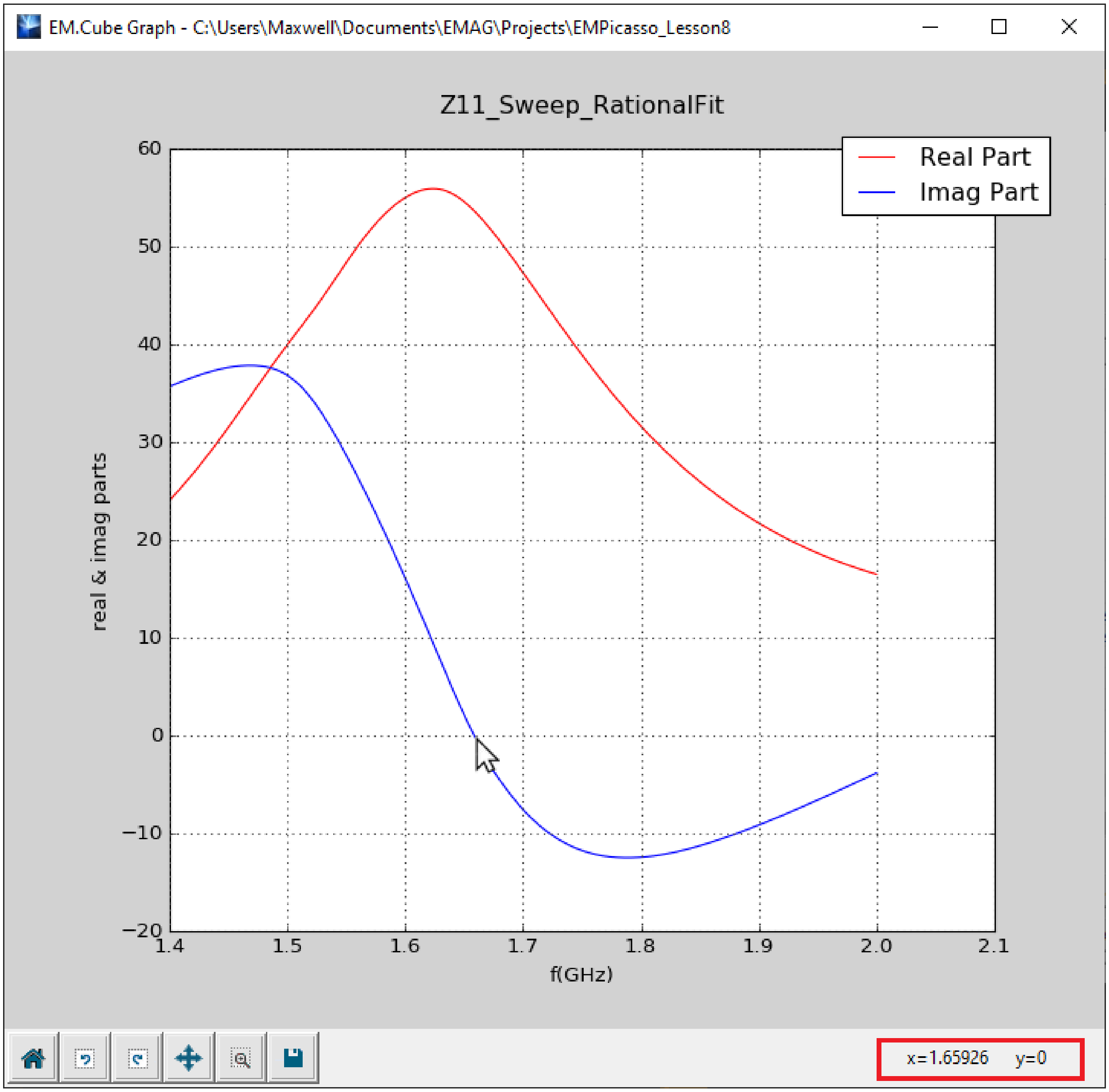



***Figure 13.*** *The graph of the Z11 parameter (input impedance) of the folded slot antenna.*

Finally, move the mouse to the bottom of the voltage standing wave ratio (VSWR) minima in the graph. It shows that the minimum VSWR is 1.064 (Figure 14).

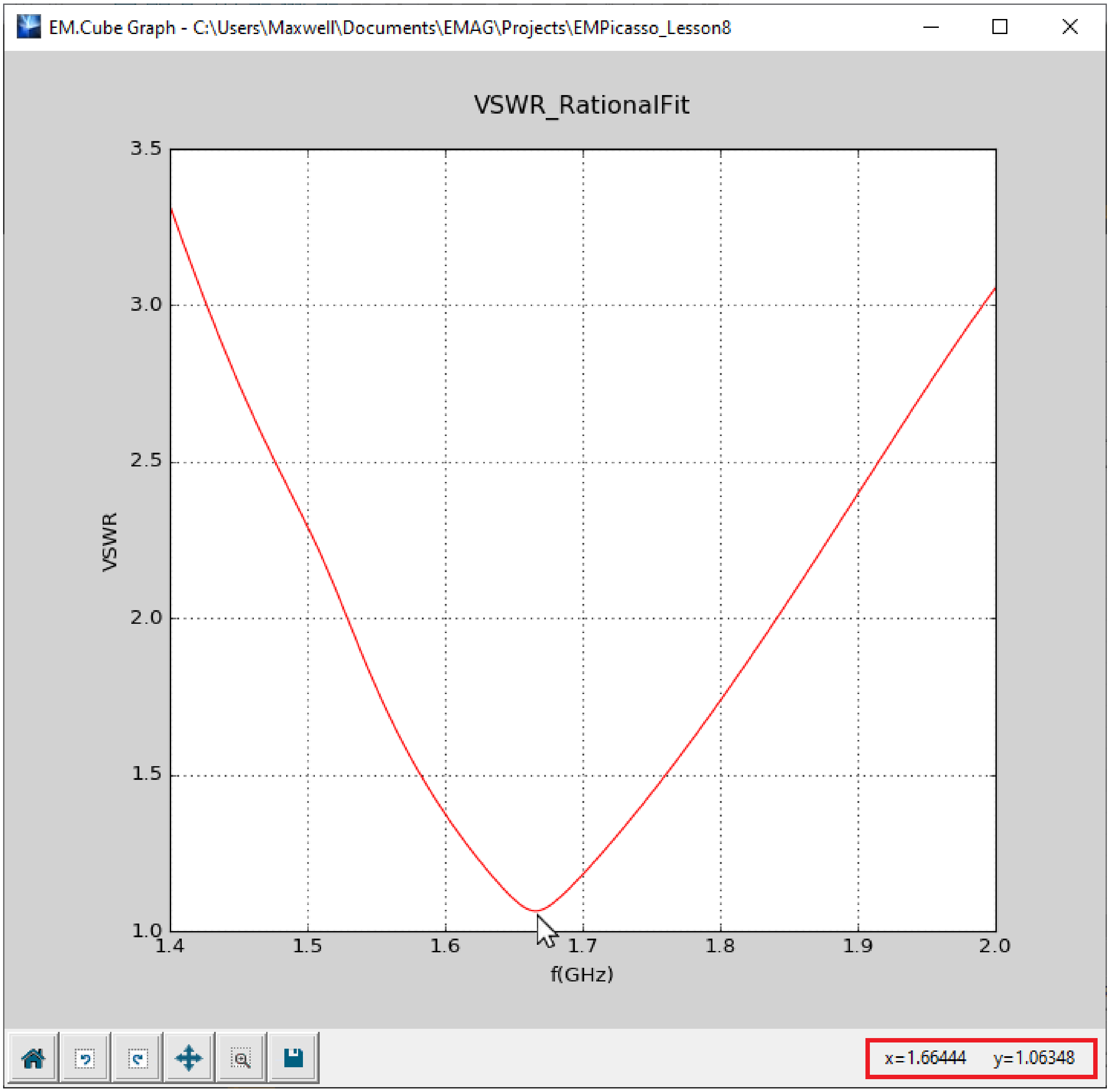
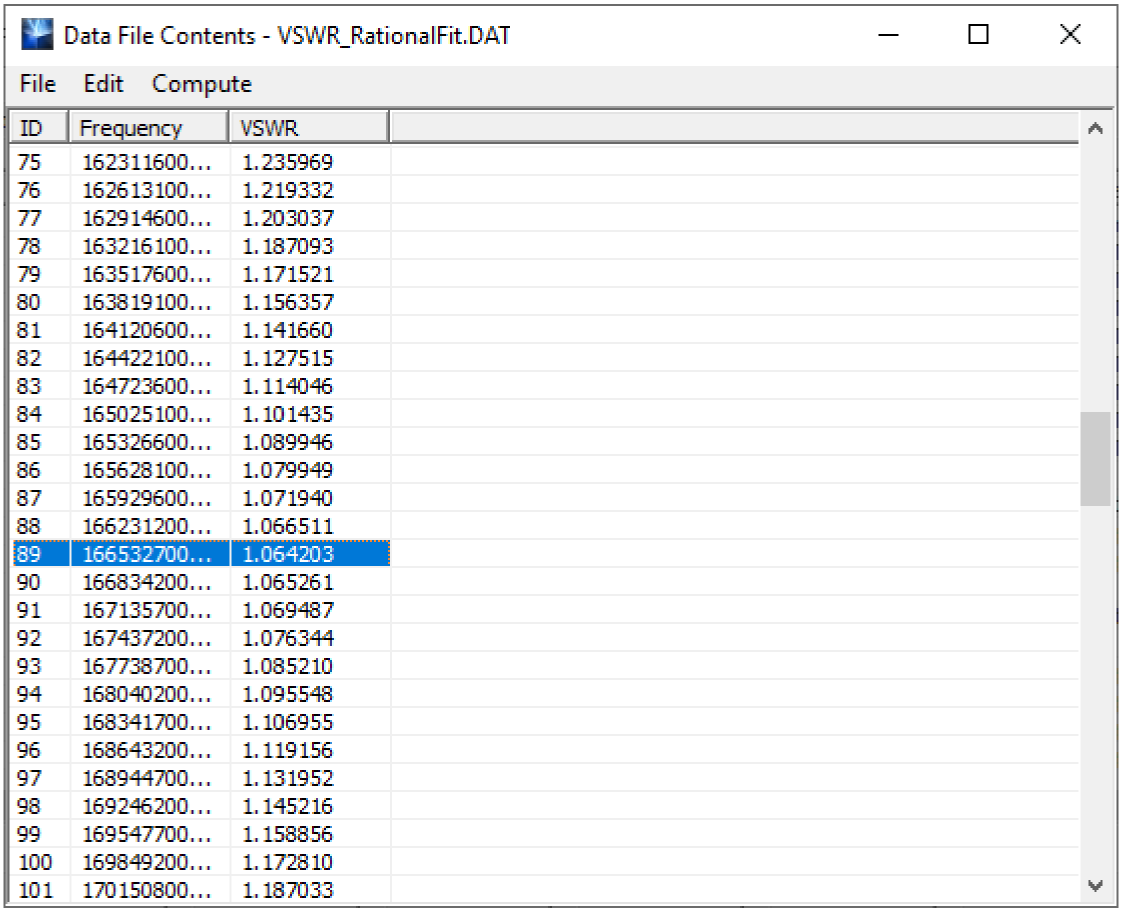



***Figure 14.*** *The graph of the voltage standing wave ratio (VSWR) of the folded slot antenna.*

Alternatively, you can view the contents of the data file “VSWR_Sweep_RationalFit.DAT” in the spreadsheet using the **View** button in the Data Manager (Figure 15).




| ID | Frequency | VSWR |
|---|---|---|
| 75 | 162311600... | 1.235969 |
| 76 | 162613100... | 1.219332 |
| 77 | 162914600... | 1.203037 |
| 78 | 163216100... | 1.187093 |
| 79 | 163517600... | 1.171521 |
| 80 | 163819100... | 1.156357 |
| 81 | 164120600... | 1.141660 |
| 82 | 164422100... | 1.127515 |
| 83 | 164723600... | 1.114046 |
| 84 | 165025100... | 1.101435 |
| 85 | 165326600... | 1.089946 |
| 86 | 165628100... | 1.079949 |
| 87 | 165929600... | 1.071940 |
| 88 | 166231200... | 1.066511 |
| 89 | 166532700... | 1.064203 |
| 90 | 166834200... | 1.065261 |
| 91 | 167135700... | 1.069487 |
| 92 | 167437200... | 1.076344 |
| 93 | 167738700... | 1.085210 |
| 94 | 168040200... | 1.095548 |
| 95 | 168341700... | 1.106955 |
| 96 | 168643200... | 1.119156 |
| 97 | 168944700... | 1.131952 |
| 98 | 169246200... | 1.145216 |
| 99 | 169547700... | 1.158856 |
| 100 | 169849200... | 1.172810 |
| 101 | 170150800... | 1.187033 |

***Figure 15.*** *The contents of the data file "VSWR_RationalFit.DAT" shown in data manager's spreadsheet.*