EM.Picasso
Tutorial Lessons

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9

EM.Picasso Tutorial Lesson 9

Designing a Microstrip Wilkinson Power Divider

Table of Contents

9.1 What You Will Learn

In this tutorial you will build and simulate a three-port planar circuit. You will also learn how to define a lumped element on a strip object to represent a lumped resistor.

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:

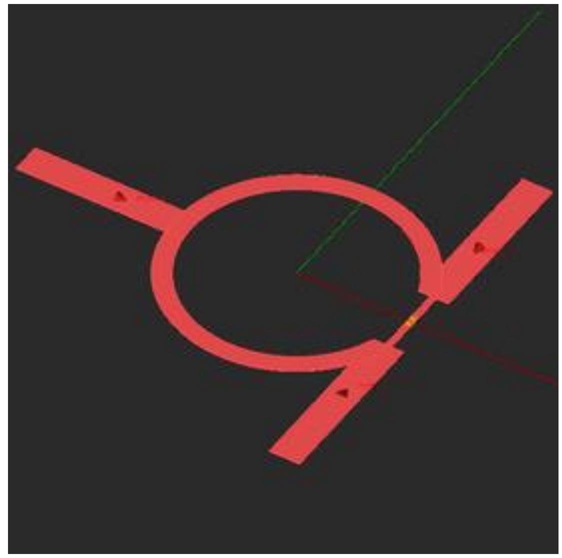
http://www.emagtech.com/downloads/ProjectRepo/EMPicasso_Lesson9.zip

9.2 Getting Started

Start a new project with the following parameters:

Starting Parameters	
Name	EMPicasso_Lesson9
Length Units	Millimeters
Frequency Units	GHz
Center Frequency	2.4GHz
Bandwidth	1GHz

Tutorial Project: Designing a Microstrip Wilkinson Power Divider



Objective: In this project, you will build a microstrip Wilkinson power divider using three scattering wave ports and a lumped element.

Concepts/Features:

- PEC Trace
- Rectangle Strip
- Circle Strip
- Scattering Wave Port Source
- Port Definition
- Lumped Element
- Resistor
- Planar Mesh
- S-Parameters

Minimum Version Required: All versions

Substrate Configuration	
Number of Finite Layers	1
Top Half-Space	Vacuum
Top Layer	ROGER RT/Duroid 5880: $\varepsilon_r = 2.2, \mu_r = 1, \sigma = \sigma_m = 0$, Thickness = 0.787mm
Bottom Half-Space	PEC

9.3 Drawing the Power Divider Structure & Assigning Its Plots

Create a PEC group called "PEC_1" on the navigation tree. The Wilkinson power divider will consist of two different microstrip line types with characteristics impedance values of $Z_0 = 50\Omega$ and $\sqrt{2}Z_0 = 70.7\Omega$. On the particular substrate of this project as specified in the above table, the widths of the two microstrip lines will be 2.4mm and 1.4mm, respectively. The ring strip will serve as the two 70.7Ω quarter-wave arms of the Wilkinson power divider.

Draw a circle strip object using its **Outer Radius**, **Inner Radius**, **Start Angle** and **End Angle** parameters given in the table below:

Label	Object Type	LCS Origin	Inner Radius	Outer Radius	Start Angle	End Angle
Arc	Circle Strip (75Ω Arm)	(0, 0, 0.787mm)	8.25mm	9.65mm	20°	340°

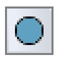
To draw a circle or arc, click the **Circle Strip**  button of the **Object Toolbar** (Figure 1) or select the menu item **Object** → **Surface** → **Circle Strip** or use the keyboard shortcut **Alt+C** (Figure 2).

Figure 1. *Selecting the Circle Strip tool in the Object Toolbar.*

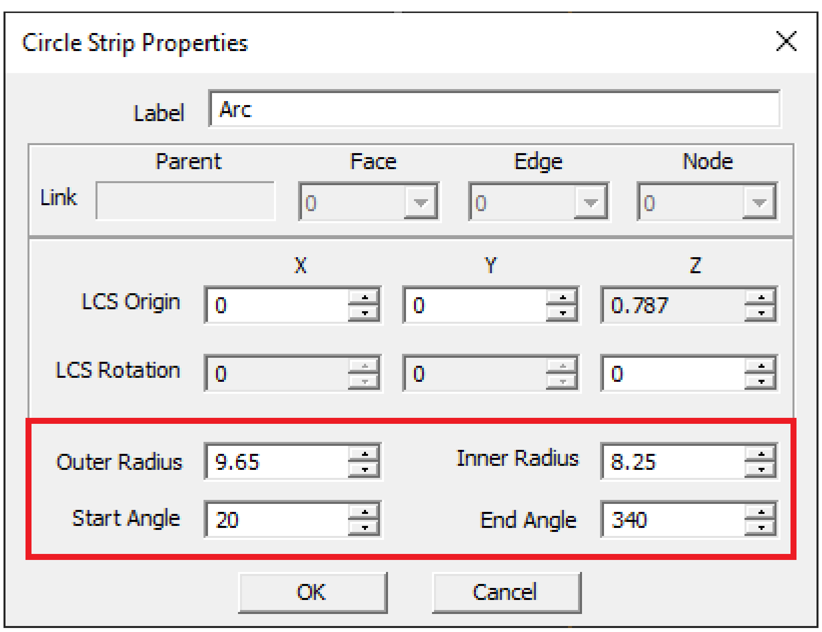


Figure 2. *The property dialog of the Circle Strip object.*

Next, draw six rectangle strip objects with dimensions and locations given in the table below:

Label	Object Type	LCS Origin	X Dimension	Y Dimension
Rect1	Rectangle Strip (50Ω Input Line)	(-10.75mm, 0, 0.787mm)	5mm	2.4mm
Rect2	Rectangle Strip (50Ω Input Line)	(8.95mm, -5.3mm, 0.787mm)	2.4mm	5mm
Rect3	Rectangle Strip (50Ω Input Line)	(8.95mm, 5.3mm, 0.787mm)	2.4mm	5mm
Rect4	Rectangle Strip (50Ω Port Line)	(-17.25mm, 0, 0.787mm)	8mm	2.4mm
Rect5	Rectangle Strip (50Ω Port Line)	(8.95mm, -11.8mm, 0.787mm)	2.4mm	8mm
Rect6	Rectangle Strip (50Ω Port Line)	(8.95mm, 11.8mm, 0.787mm)	2.4mm	8mm

Define three scattering wave port sources and assign them to the last three strip objects according to the table below:

Source Label	Host Strip Object	Direction
WP_1	Rect1	+X
WP_2	Rect5	+Y
WP_3	Rect6	-Y

Your physical structure will look like Figure 3 as shown below:

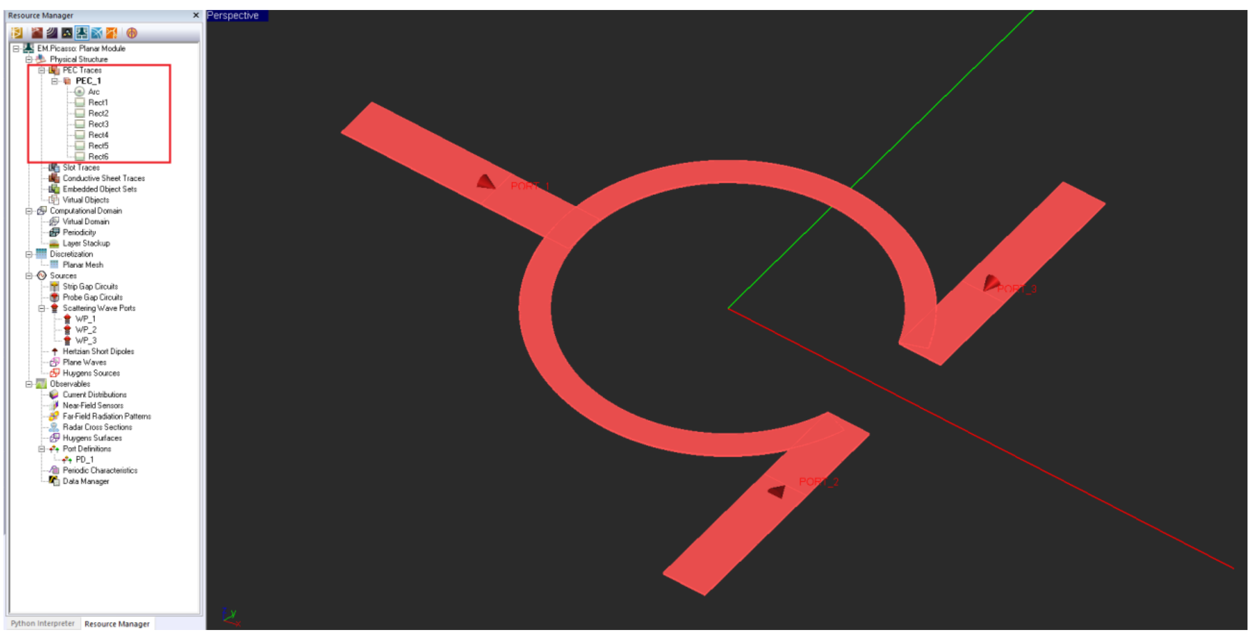
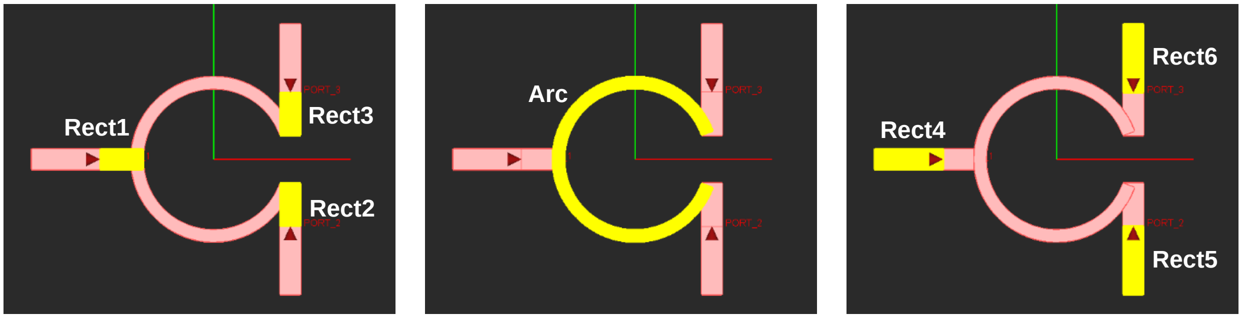


Figure 3. *The geometry of the Wilkinson power divider with three scattering wave ports.*

Figure 4 shows different segments of the Wilkinson power divider structure.



The 50Ω input lines — The 70.7Ω arm of divider — The 50Ω port lines

Figure 4. *The segments of Wilkinson power divider structure.*

9.4 Examining the Planar Mesh

Open the Planar Mesh Settings dialog and change the mesh density to 30 cells per effective wavelength. Generate the mesh of your physical structure as shown in the Figure 5. Note how the three line segments Rect1, Rect2 and Rect3 have merged with the circular arc-ring, Arc, and a consistent mesh has been generated.

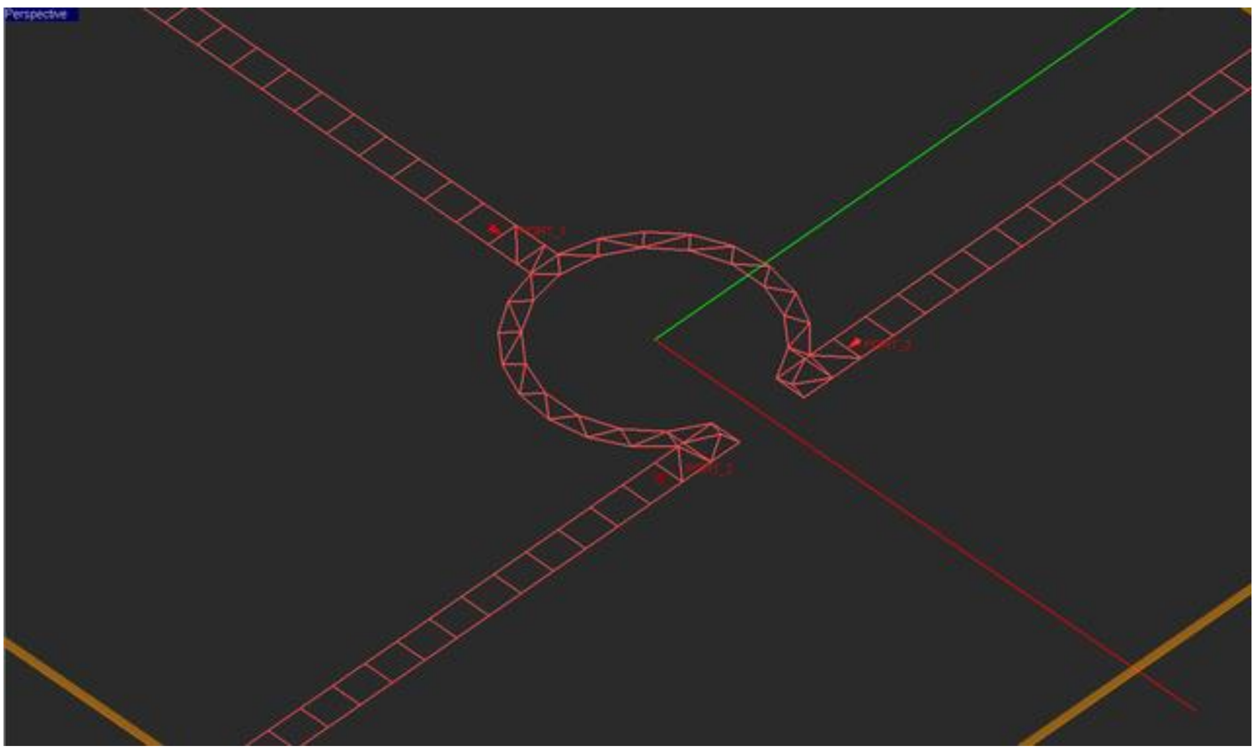


Figure 5. *The planar mesh of the Wilkinson power divider.*

Before generating a planar mesh, EM.Picasso performs a Boolean union operation on all the objects belonging to the same trace group. All the geometrical overlaps between adjacent objects are resolved as part of meshing.

It is a good practice to inspect the mesh carefully before running a Planar MoM simulation. Figure 6 shows some narrow cells in the area where the circular ring strip overlaps the port lines.

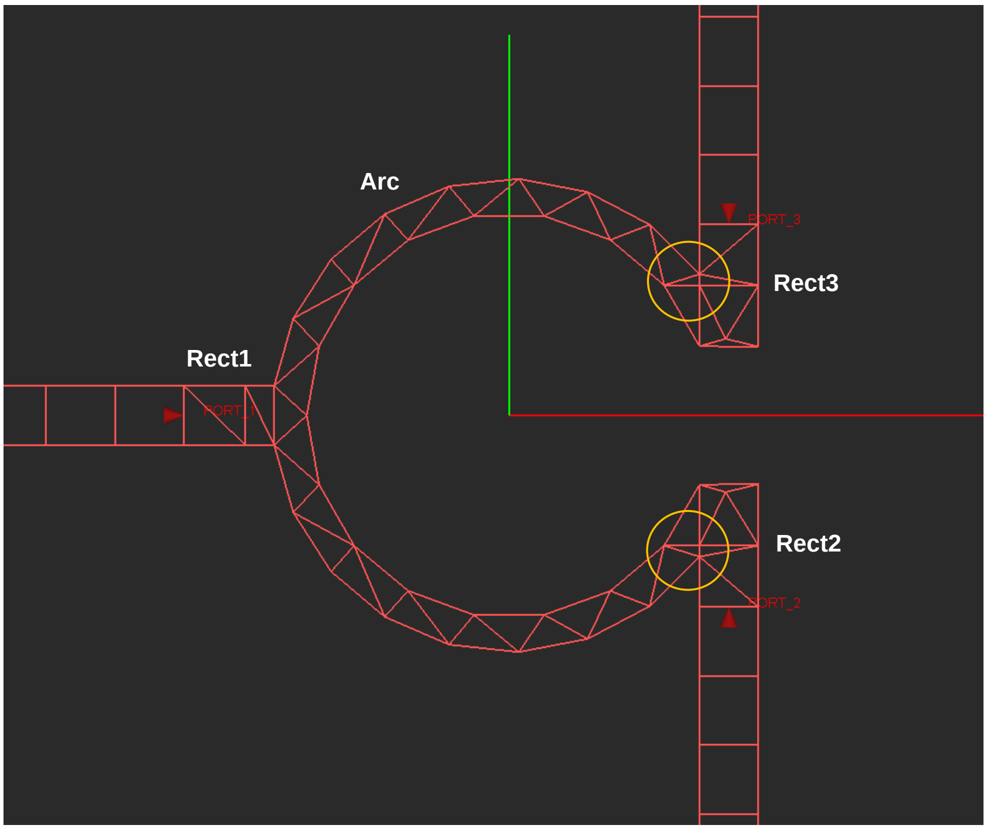


Figure 6. *Some very narrow triangular cells in the planar mesh of the Wilkinson power divider.*

9.5 Running a Frequency Sweep of the Power Divider

Run a frequency sweep of your Wilkinson power divider to examine its frequency response including return losses and insertion losses. Open the frequency sweep settings dialog from the run dialog and set the following uniform frequency sweep parameters:

Start Frequency	2GHz
End Frequency	3GHz
No. Samples	11
Fix Mesh at Center Frequency	

Note that for non-resonant structure, selecting mesh the structure at the highest frequency and option of mesh the structure at the highest frequency do not make too much of a difference.

At the end of the sweep simulation, graph three data files: “S11_Sweep.CPX”, “S22_Sweep.CPX”, “S21_Sweep.CPX” and “S32_Sweep.CPX”. **Make sure to scale the plots appropriately**. From the graphs, you can see that the insertion loss values |S21| and |S31| are about -3dB over the entire frequency range. However, the output return losses |S22| and |S33| are about -6dB, which are not good at all. You would also like to decrease the coupling |S32| between the two output ports to much lower than -7dB.

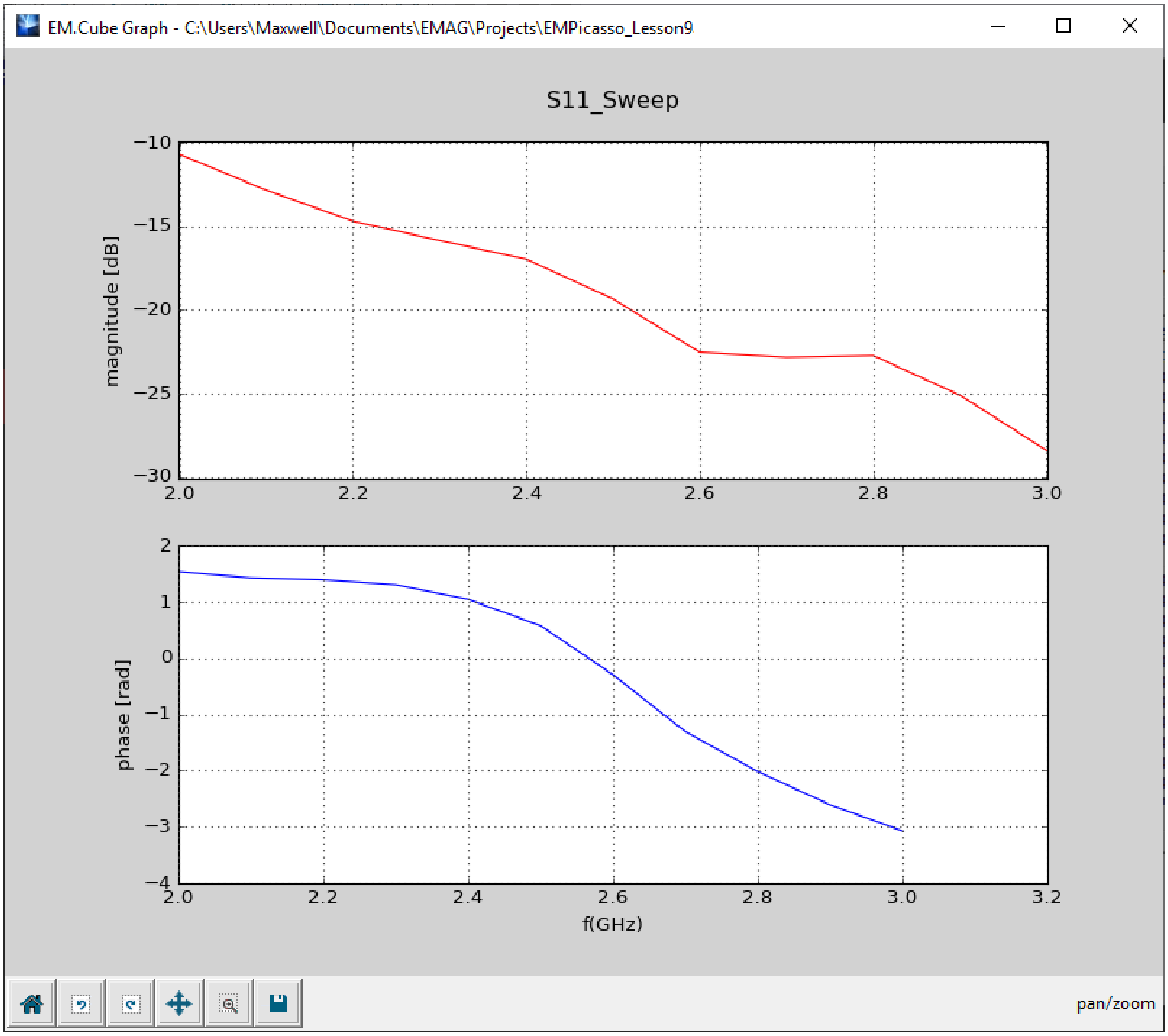


Figure 6. *The graph of the S11 parameter of the Wilkinson power divider.*

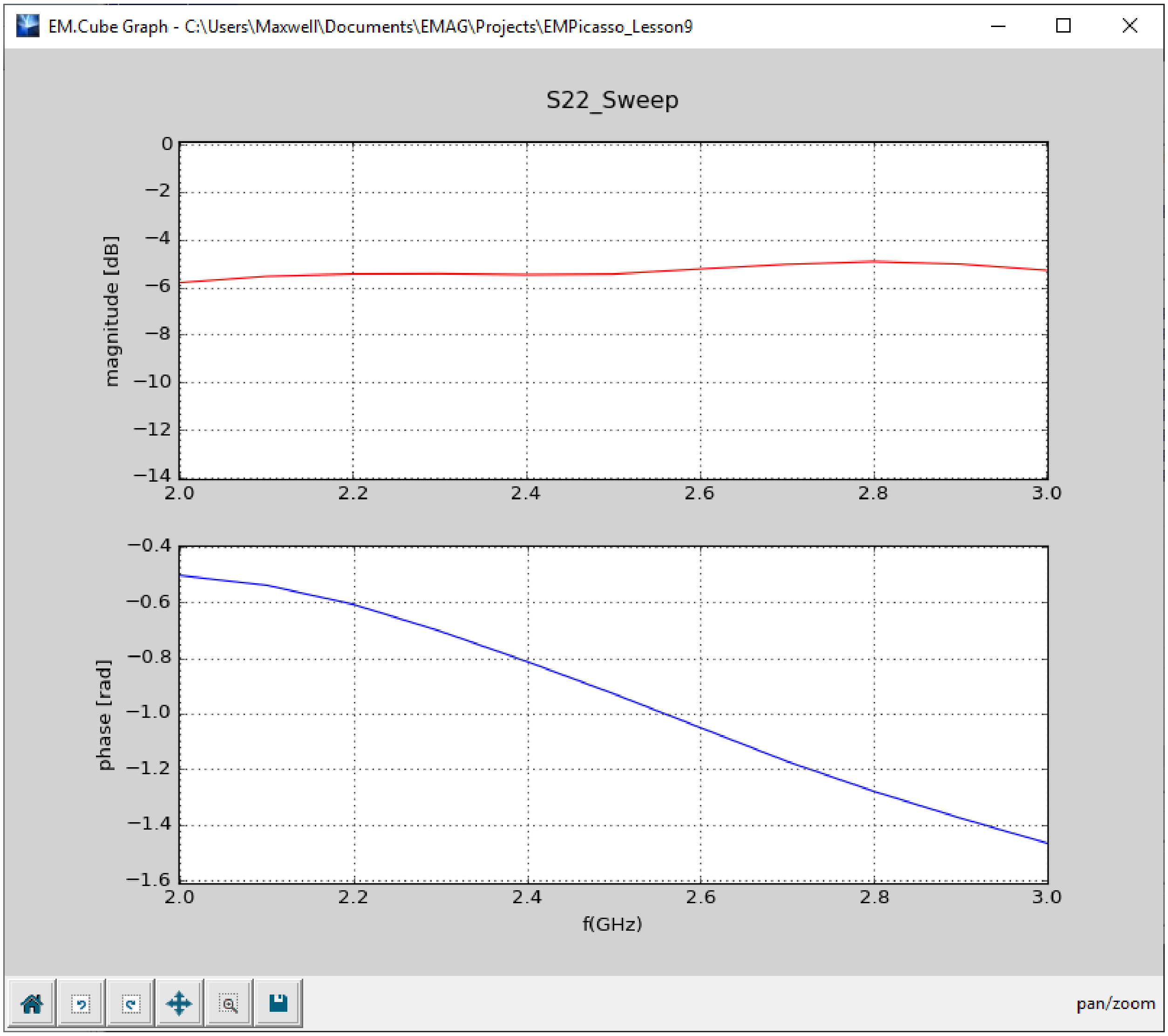


Figure 7. *The graph of the S22 parameter of the Wilkinson power divider.*

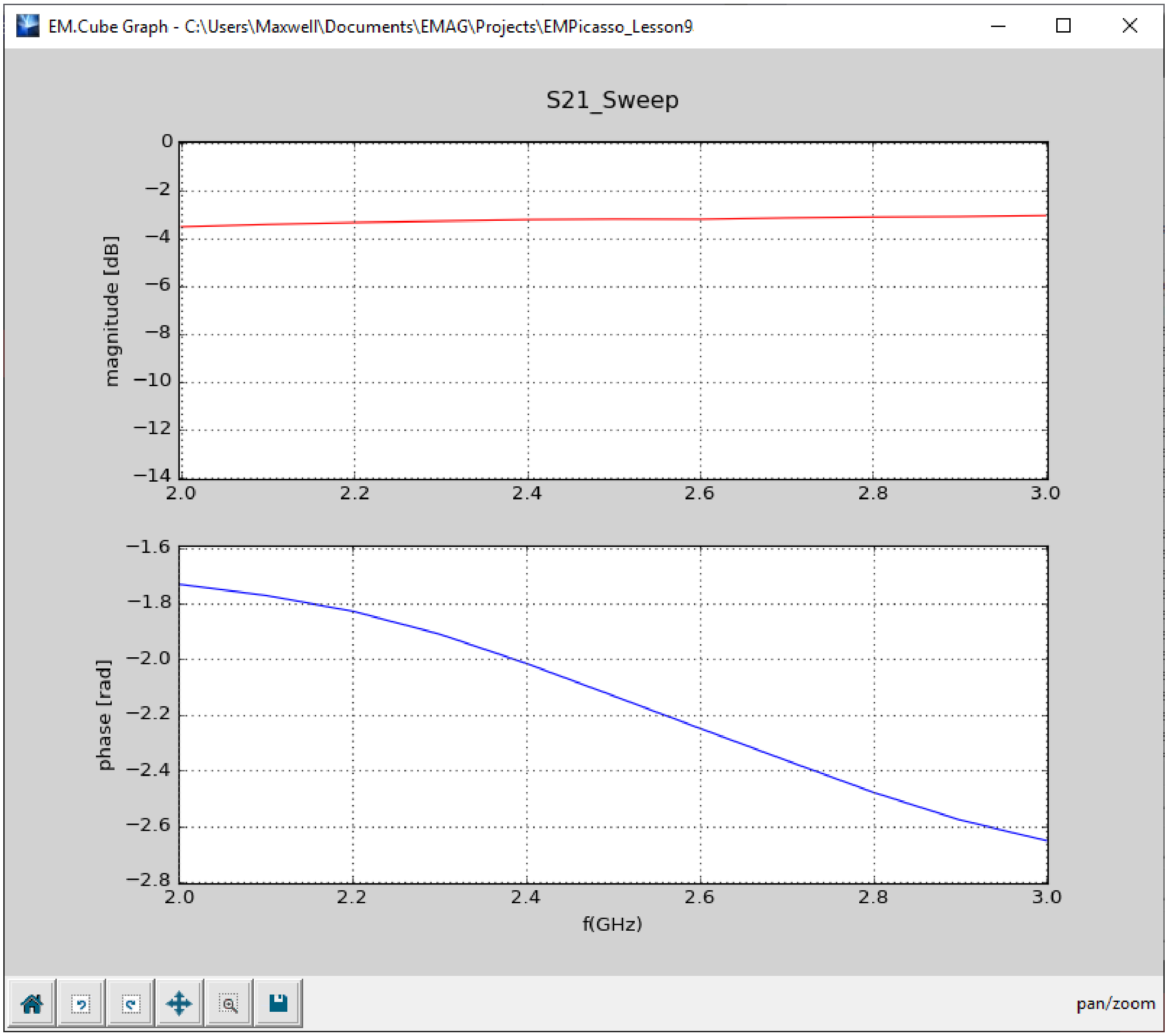


Figure 8. *The graph of the S21 parameter of the Wilkinson power divider.*

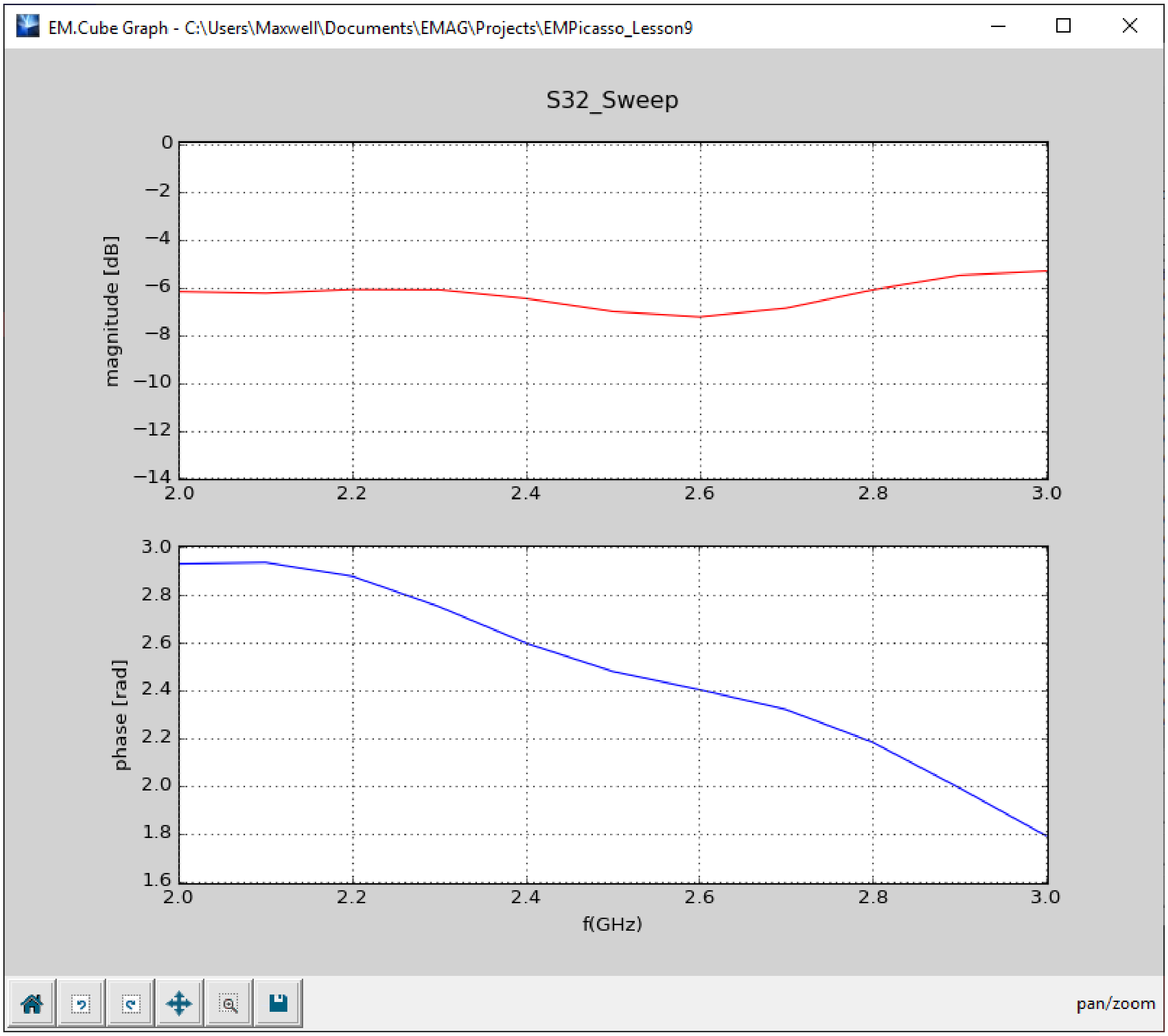


Figure 9. *The graph of the S32 parameter of the Wilkinson power divider.*

9.6 Adding a Lumped Resistor Between the Output Arms

In this part of the tutorial lesson, you will add a lumped resistor between the two output ports of your power divider to complete the Wilkinson design. But first you need to draw a narrow microstrip line segment between the two objects Rect2 and Rect3 to hold the lumped element.

> In EM.Picasso, a lumped element can only be defined in association with an existing rectangle strip object to serve as its host.

Draw a new rectangle strip object with the following parameters:

Label	Object Type	LCS Origin	X Dimension	Y Dimension
RectStrip	Rectangle Strip	(8.95mm, 0, 0.787mm)	0.5mm	5.6mm

Now you can define a lumped element to model your resistor. Go to the "Sources" section of the navigation tree, right-click on the **Strip Gap Circuits** item and select **Insert New Source...** from the contextual menu. in the source dialog, choose the name of the host line "RectStrip" from the drop-down list. Select **Passive RLC** for the lumped circuit type.

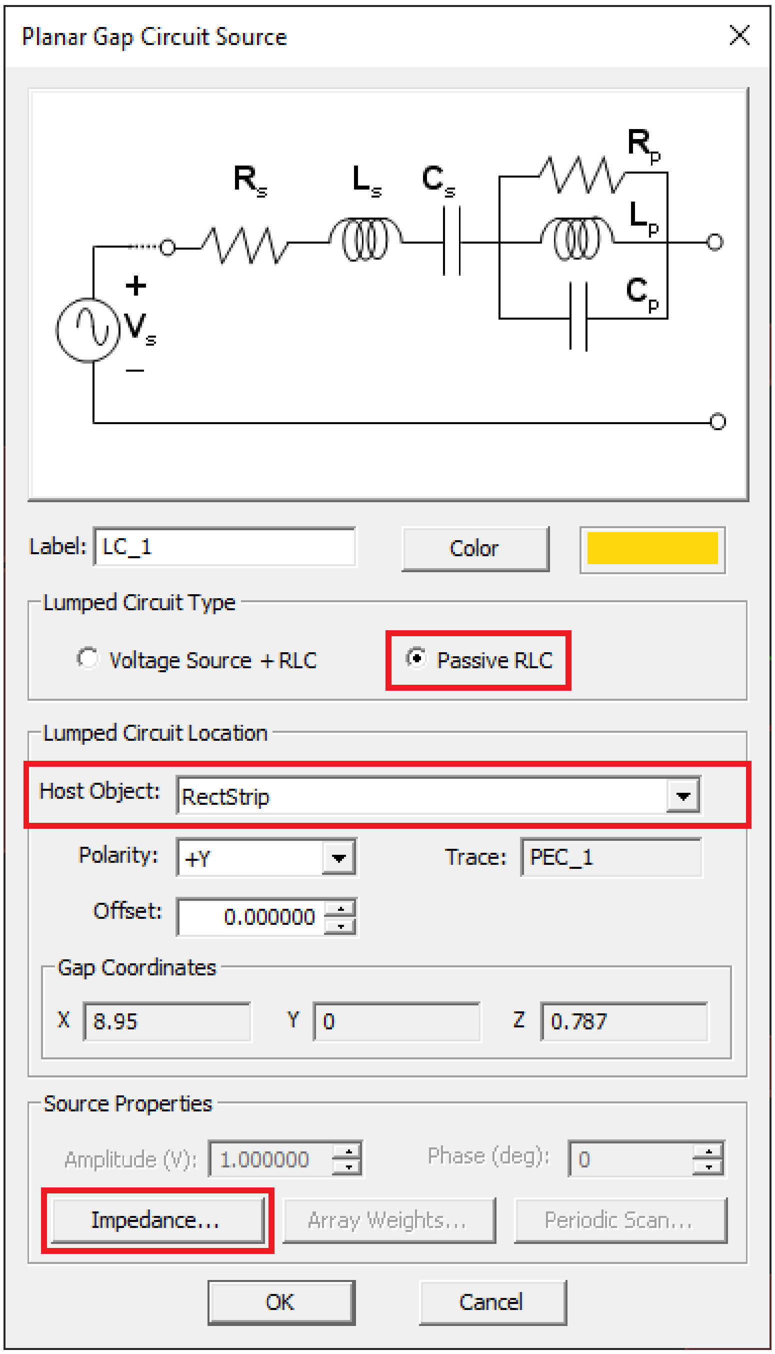


Figure 10. *EM.Picasso's lumped gap circuit dialog showing "Passive RLC" as the lumped circuit type.*

Click on the **Impedance...** button of this dialog to open the lumped element impedance dialog. By default the box labeled "Rs (Ohm)" is checked with a default resistance value of 50Ω. Change the value of resistance to 100Ω, *i.e.* $2Z_0$. Close the two nested dialogs and return to the project workspace. You will see a yellow lumped element appear at the center of the last strip object.

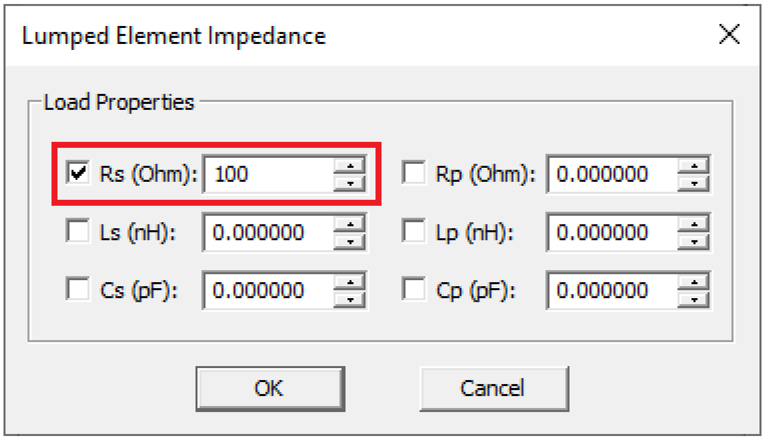


Figure 11. *The Lumped Element dialog.*

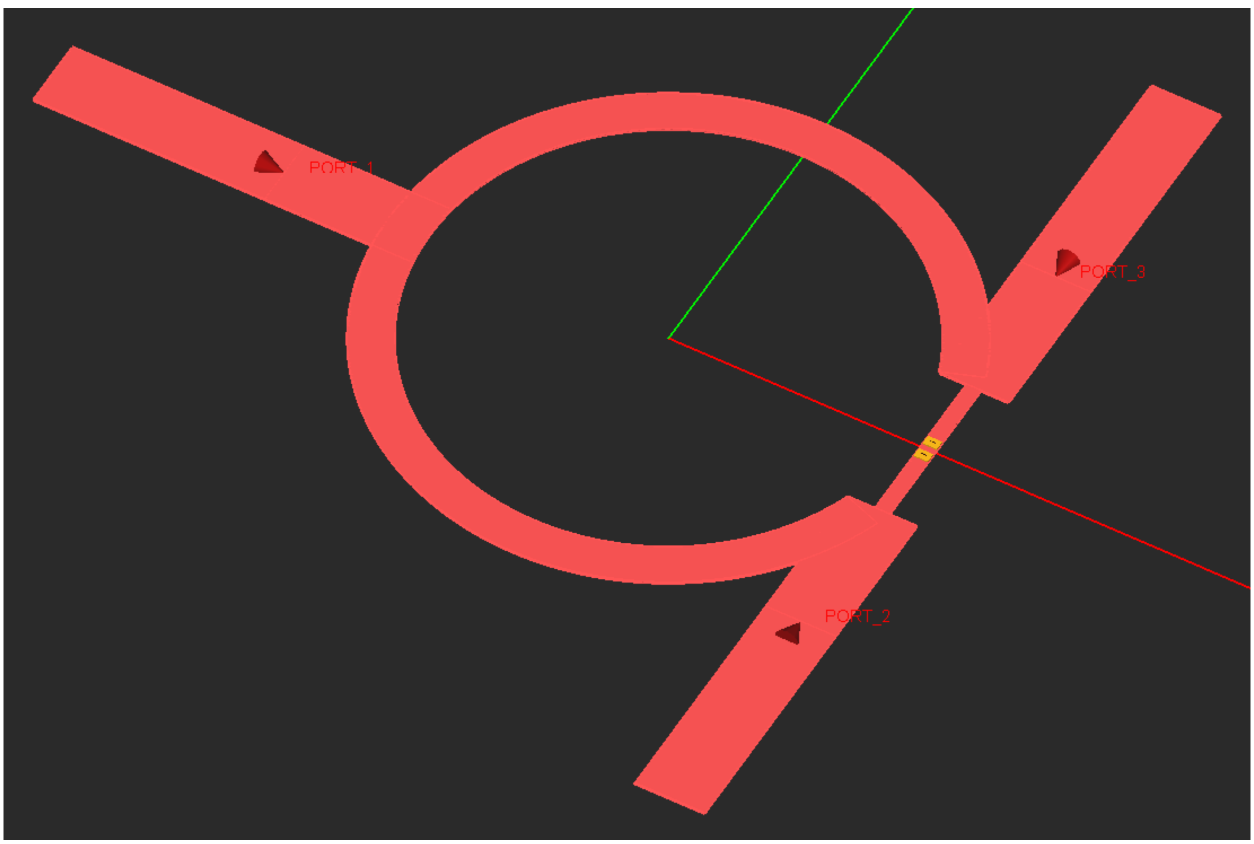


Figure 12. *The geometry of the Wilkinson power divider with the lumped resistor.*

9.7 Examining the Planar Mesh of the Power Divider with the Lumped Resistor

The presence of the narrow microstrip line segment hosting the resistive lumped element acts like a discontinuity. As a result, it requires a high resolution mesh even though the segment's size is quite small. Open the planar mesh settings dialog and check the box labeled **Refine Mesh at Gap Locations**.

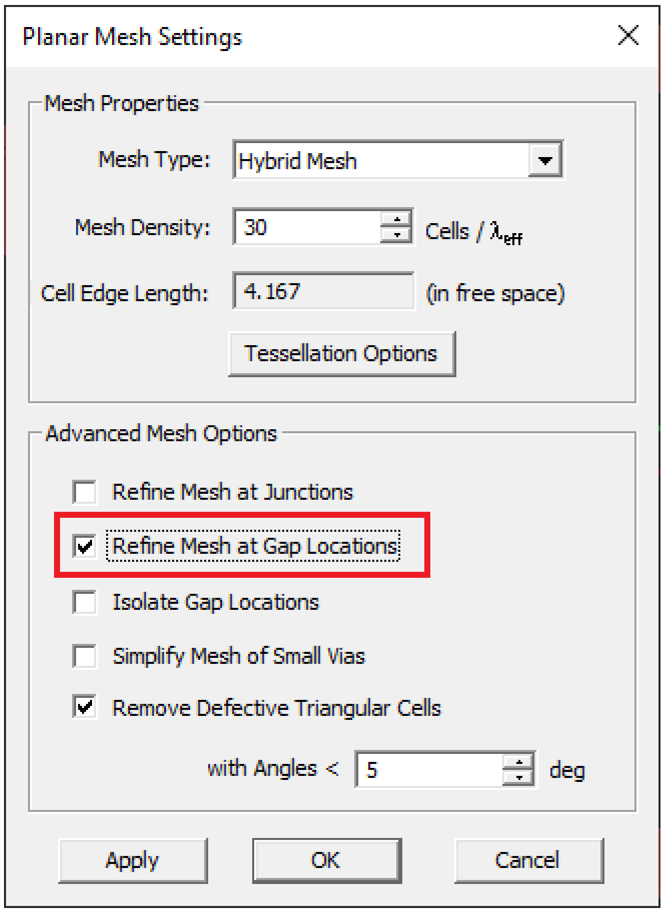


Figure 13. *EM.Picasso's mesh settings dialog.*

Now generate the mesh of the planar structure with the same mesh density of 30 cells per effective wavelength.

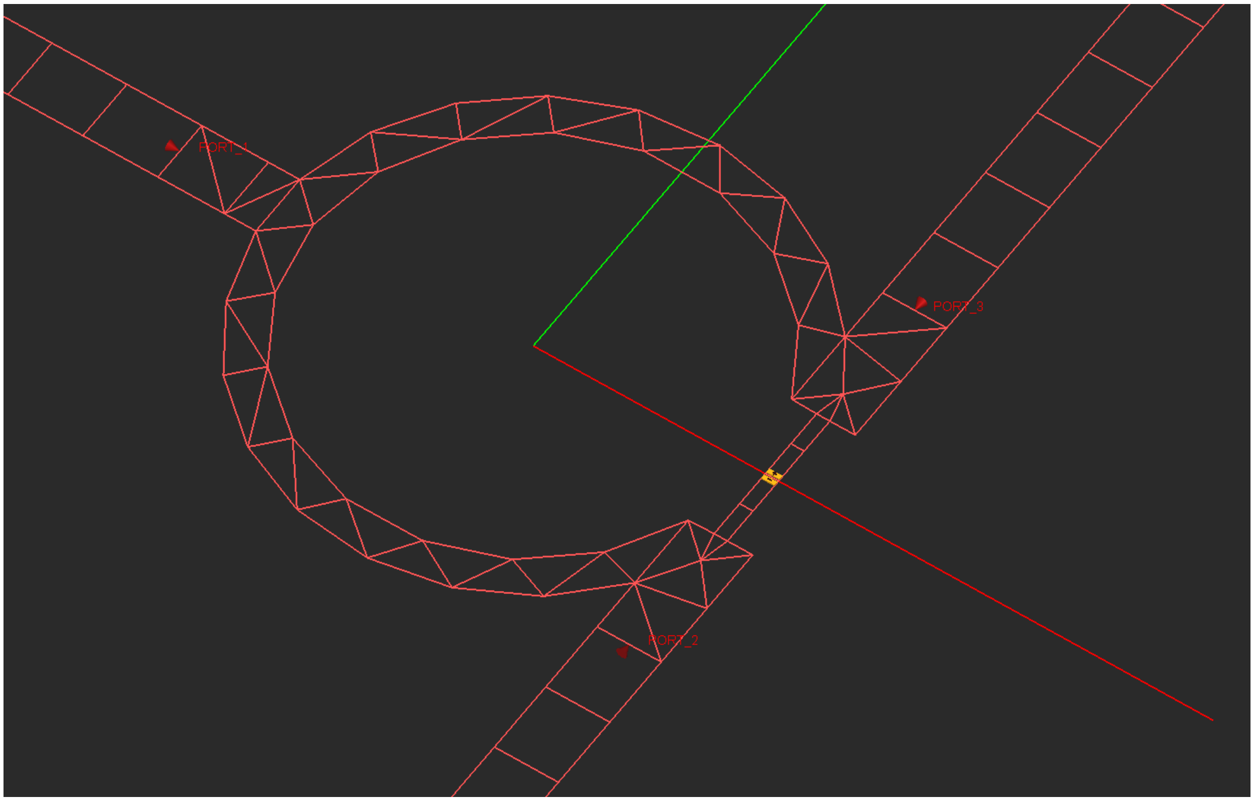


Figure 14. *The planar mesh of the Wilkinson power divider with the lumped resistor.*

9.8 Simulating the Complete Wilkinson Power Divider

Run a frequency sweep of your Wilkinson power divider with the added resistor. Set the following uniform frequency sweep parameters and keep the option to mesh the structure at the center frequency of the project during the entire sweep.

Start Frequency	2GHz
End Frequency	3GHz
Number of Frequency Samples	11

At the end of the sweep simulation, graph three data files: “S11_Sweep.CPX”, “S22_Sweep.CPX”, “S21_Sweep.CPX” and “S32_Sweep.CPX”. Make sure to scale the plots properly.

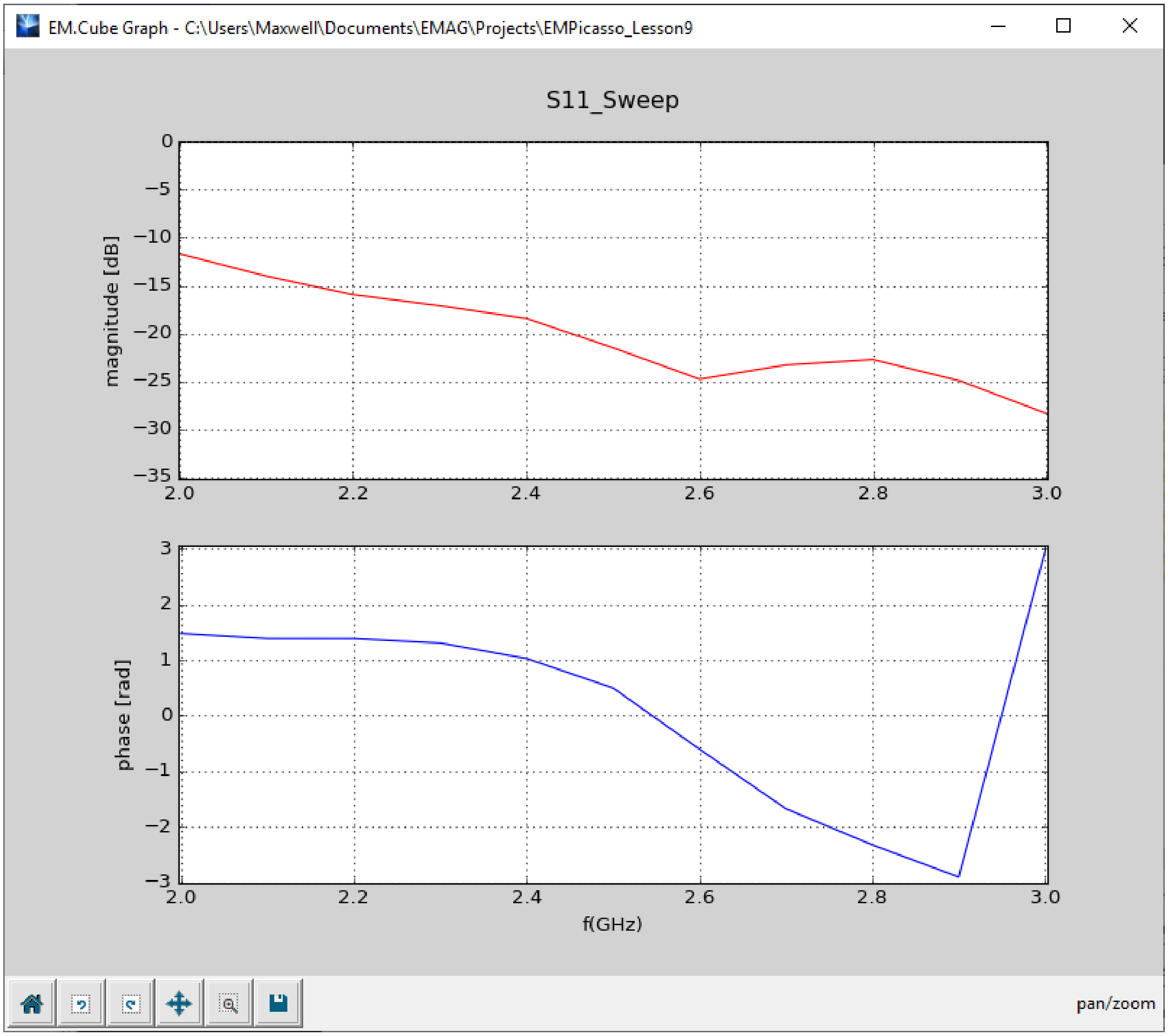


Figure 15. *The graph of the S11 parameter of the Wilkinson power divider with the lumped resistor.*

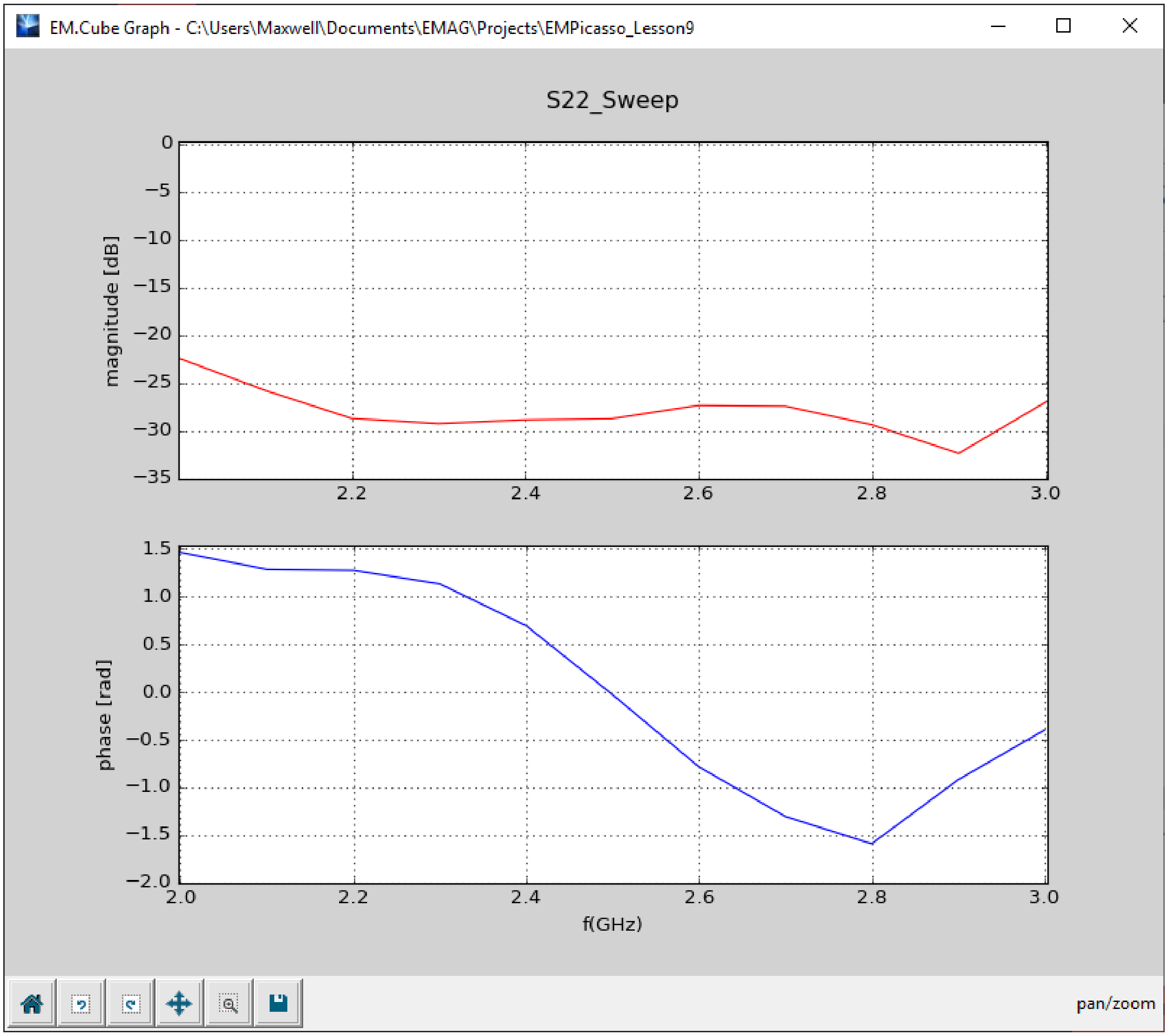


Figure 16. *The graph of the S22 parameter of the Wilkinson power divider with the lumped resistor.*

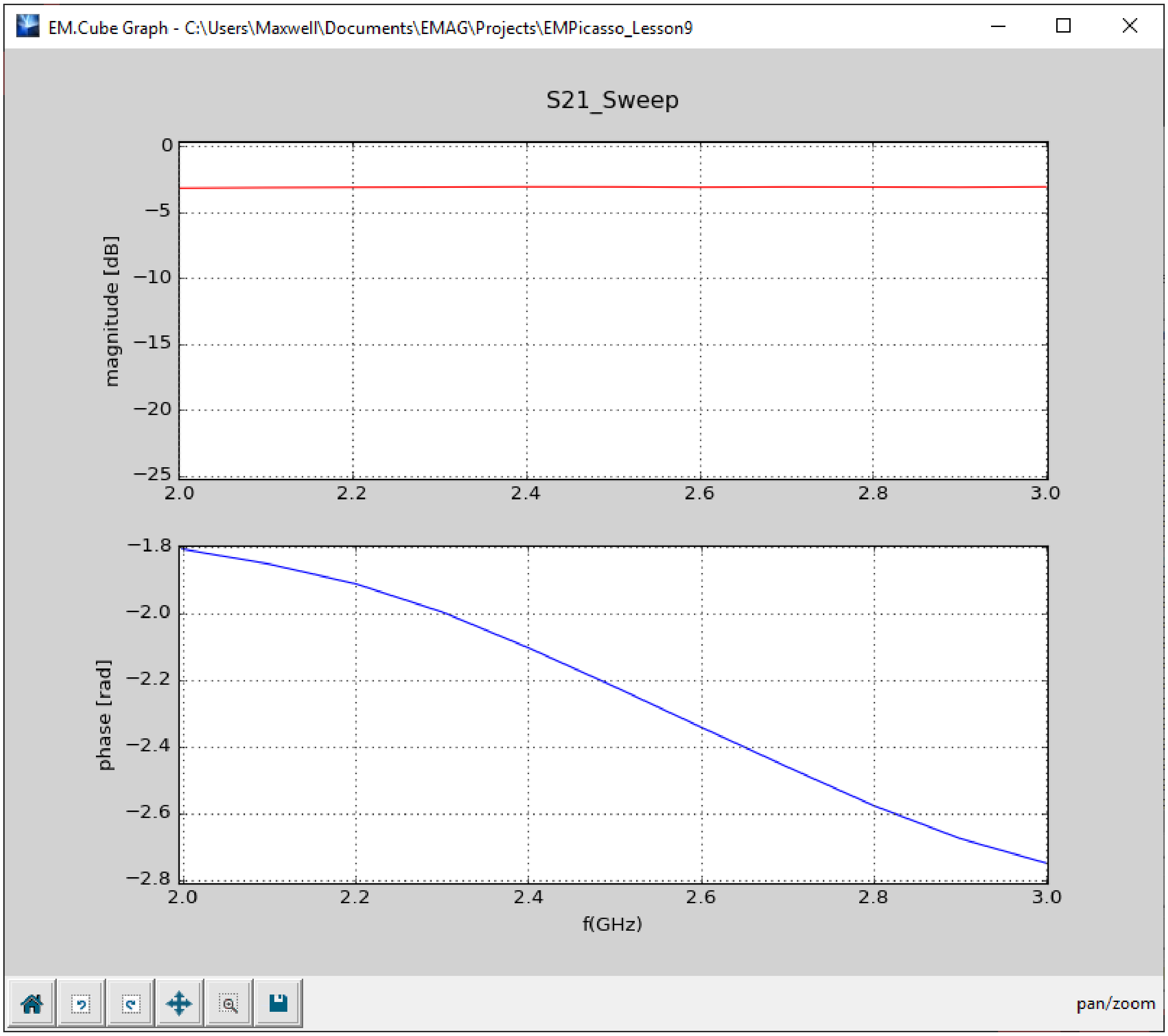


Figure 17. *The graph of the S21 parameter of the Wilkinson power divider with the lumped resistor.*

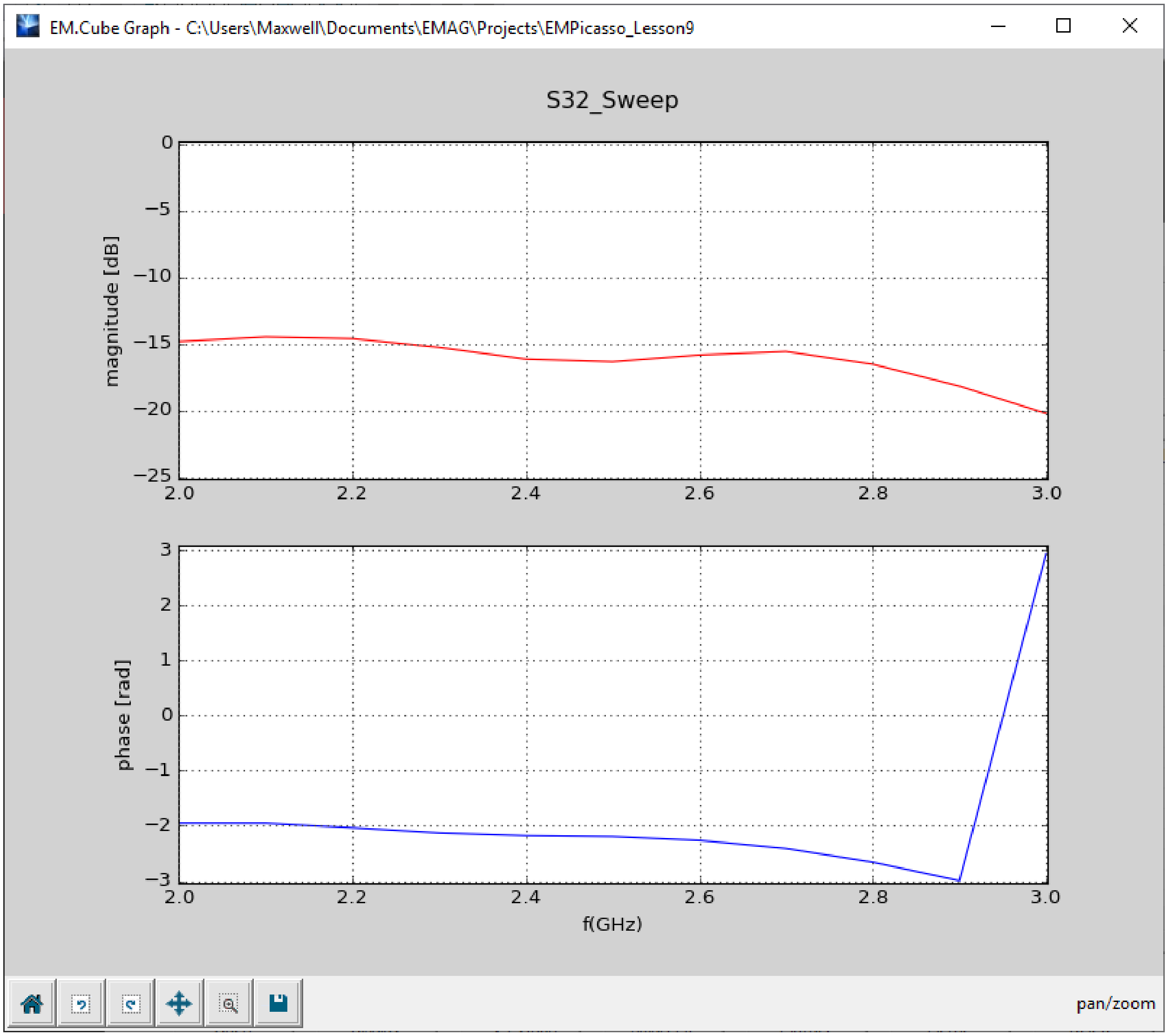


Figure 18. *The graph of the S32 parameter of the Wilkinson power divider with the lumped resistor.*

From the above figures, you can see that all three port are well matched. The insertion loss at the two output ports is -3.1dB, and the coupling between the output ports has dropped to lower than -16dB.

The table below shows the values of all the S-parameters at the center frequency of the project fc = 2.4GHz.

S-Parameter	Complex Value	Magnitude
S_{11}	0.062105 +0.102575j	-18.422815dB
S_{12}	-0.288712 -0.6371611j	-3.103991dB
S_{13}	-0.286305 -0.639026j	-3.095162dB
S_{21}	-0.356279 -0.603987j	-3.082689dB
S_{22}	0.027614 +0.023051j	-28.881054dB
S_{23}	-0.088694 -0.127873j	-16.158593dB
S_{31}	-0.354237 -0.605780j	-3.076350dB
S_{32}	-0.088719 -0.127853j	-16.158715dB
S_{33}	0.025392 +0.016938j	-30.307474dB