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EM.Picasso

Tutorial Lessons

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EM.Picasso Tutorial Lesson 10

Optimizing a Microstrip Patch Antenna Design

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10.1 What You Will Learn

In this tutorial you will revisit the rectangular patch antenna design with a recessed feed, which you explored earlier in Tutorial Lesson 2. This time, however, you will define a design objective and will use EM.Picasso's optimization utility to optimize the values of designated design variables to achieve your goal.

EM.Picasso Manual:

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

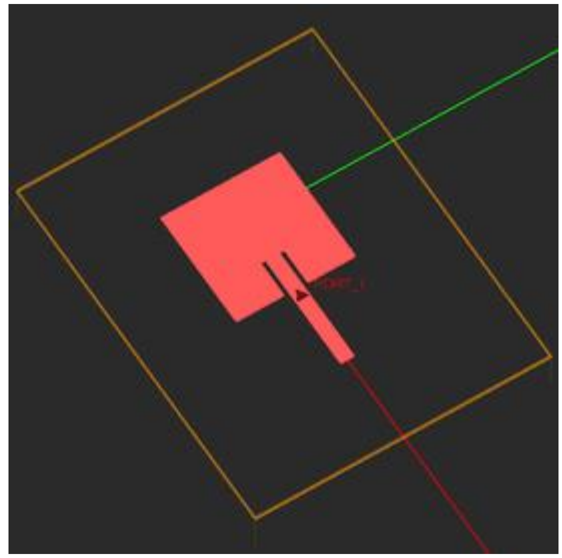
EM.Picasso Tutorial Gateway:

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_Lesson10.zip

Tutorial Project: Optimizing A Microstrip Patch Antenna Design



Objective: In this project, you will use one of EM.Cube's optimizers to design a patch antenna with a recessed microstrip feed line.

Concepts/Features:

- Wizard
- Scattering Wave Port
- Scattering Parameters
- Design Variable
- Design Objective
- Optimization
- Error Function

Minimum Version Required: All versions

10.2 Getting Started

Start a new project with the following parameters:

Starting Parameters	
Name	EMPicasso_Lesson10
Length Units	Millimeters
Frequency Units	GHz
Center Frequency	2.4GHz
Bandwidth	0.5GHz

10.3 Creating the Patch Geometry with a Recessed Feed

Follow a similar procedure as in Tutorial Lesson 2 and use the **Microstrip-Fed Patch Wizard** or select the menu item **Tools** → **Antenna Wizards** → **Microstrip-Fed Patch Antenna** to create the parameterized geometry of a patch antenna with a recessed feed. A dialog opens up asking you if you would like a patch design with a recessed feed. Answer "**Yes**" and let the wizard draw the geometry of the patch antenna with the recessed feed as shown in Figure 1.

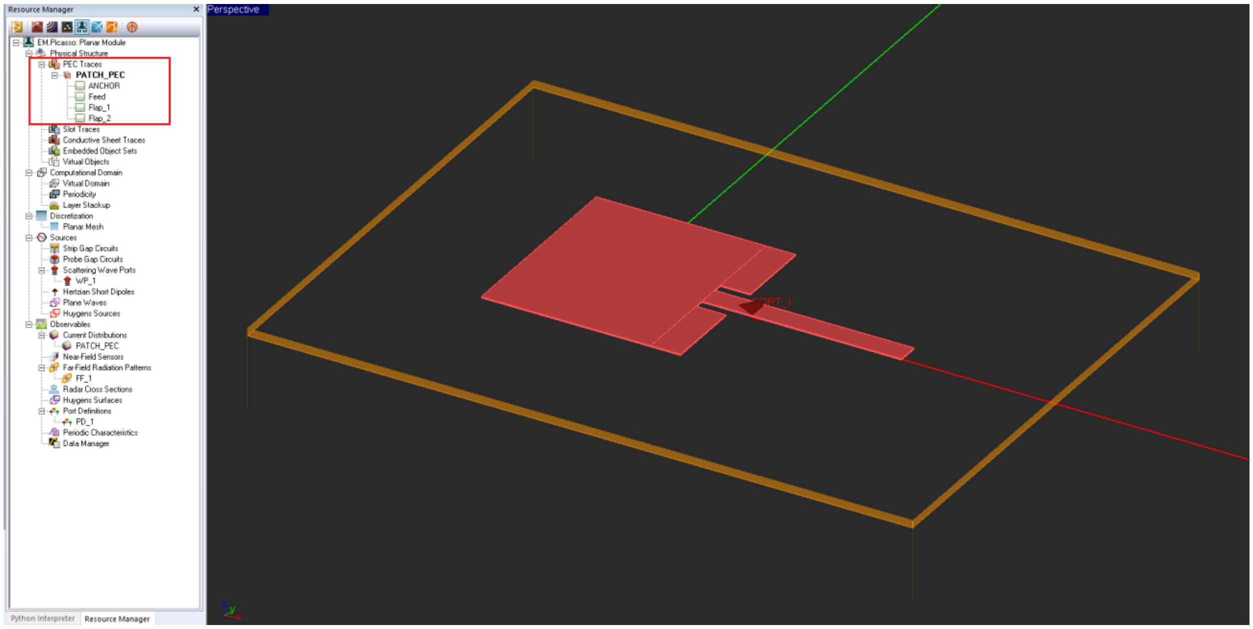
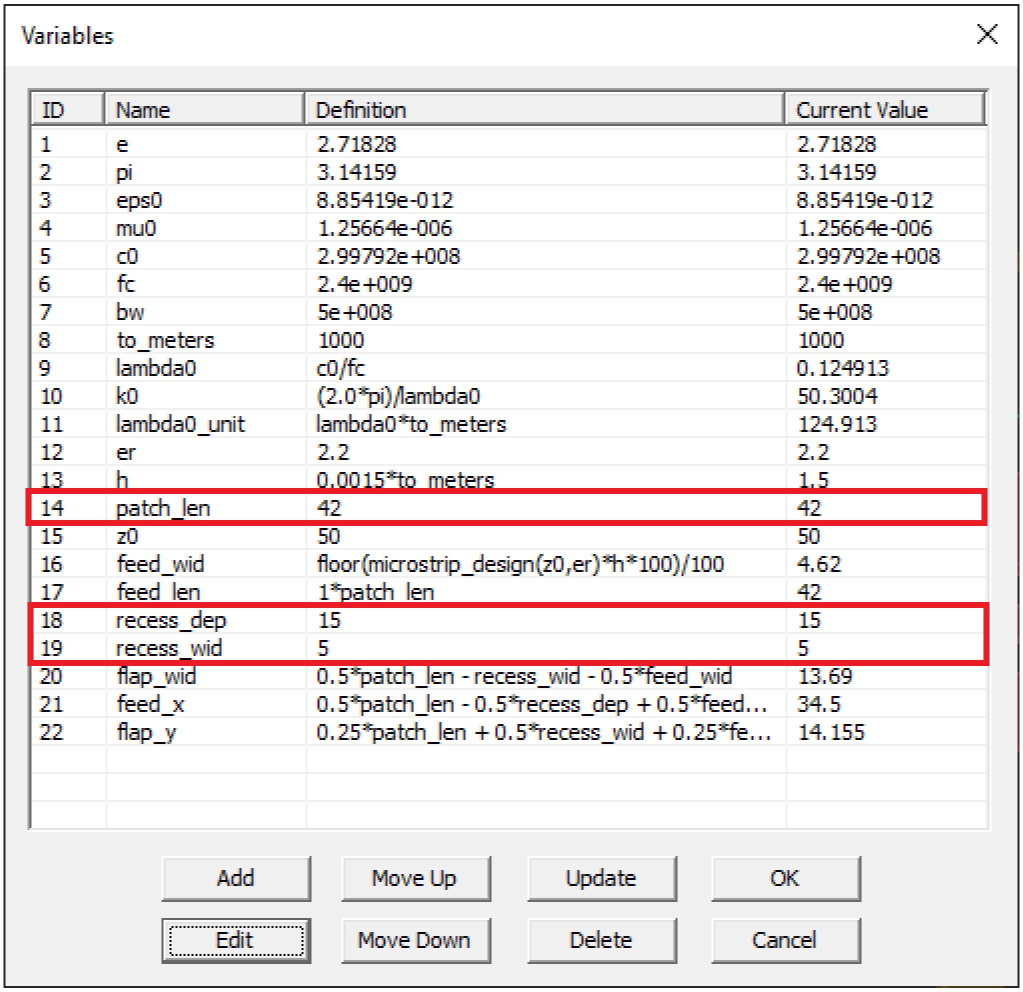


Figure 1. *The patch antenna geometry with the recessed feed in the project workspace.*

Open the Variables dialog and make the following changes (Figure 2):

Variable Name	Original Definition	New Definition
patch_len	floor(0.5*lambda0_unit*100/sqrt(er))/100	42
recess_dep	0.015*to_meters	15
recess_wid	0.005*to_meters	5



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	2.4e+009	2.4e+009
7	bw	5e+008	5e+008
8	to_meters	1000	1000
9	lambda0	c0/fc	0.124913
10	k0	(2.0*pi)/lambda0	50.3004
11	lambda0_unit	lambda0*to_meters	124.913
12	er	2.2	2.2
13	h	0.0015*to_meters	1.5
14	patch_len	42	42
15	z0	50	50
16	feed_wid	floor(microstrip_design(z0,er)*h*100)/100	4.62
17	feed_len	1*patch_len	42
18	recess_dep	15	15
19	recess_wid	5	5
20	flap_wid	0.5*patch_len - recess_wid - 0.5*feed_wid	13.69
21	feed_x	0.5*patch_len - 0.5*recess_dep + 0.5*feed...	34.5
22	flap_y	0.25*patch_len + 0.5*recess_wid + 0.25*fe...	14.155

Figure 2. *The Variables dialog showing the new definitions of some variables.*

10.4 Defining the Design Objective

In this project, you will fix the side dimensions of the patch ("patch_len"), and will optimize the two feed variables: "recess_dep" and "recess_wid". But first you need to define a design objective for your project. The goal here is to achieve a good impedance match by varying the design variables. A return loss of -20dB typically represents a very good impedance match.

To define a design objective, click on the **Objectives**  button of the **Simulate Toolbar** (Figure 3) or select the menu item **Simulate** → **Objectives...** or alternatively, use the keyboard shortcut **Ctrl+J**. EM.Cube's Objectives dialog opens up, which is initially empty (Figure 4).

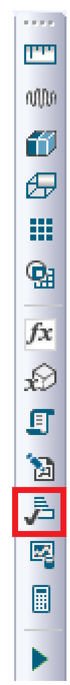


Figure 3. *The Objectives button on the Simulate Toolbar.*

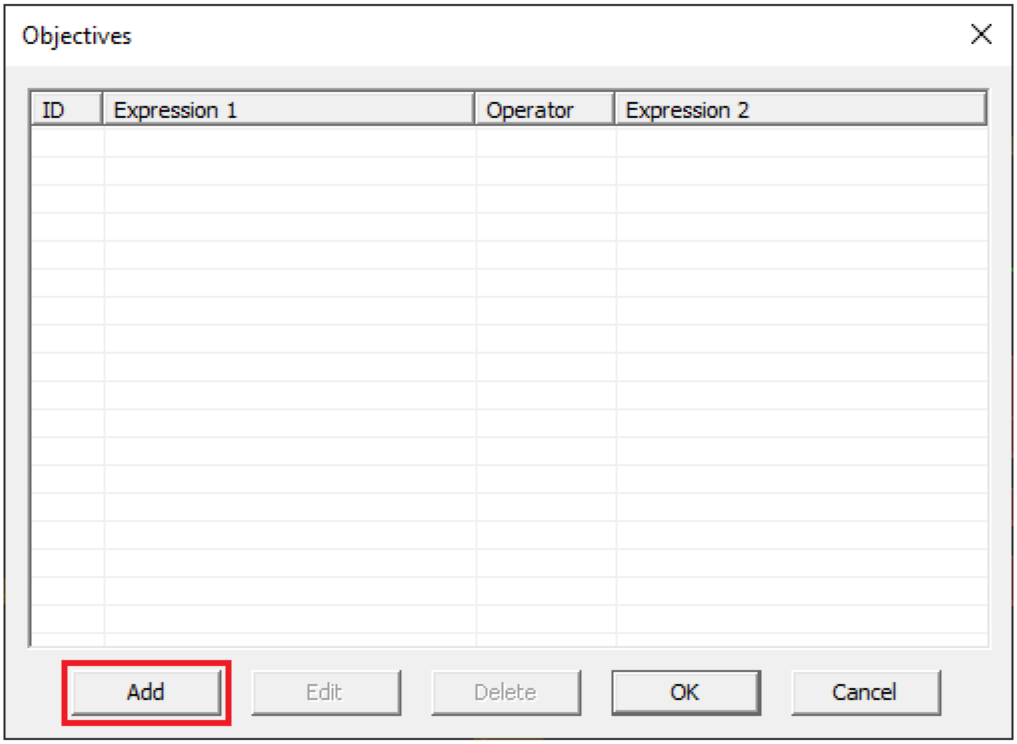


Figure 4. *EM.Cube's Objective dialog initially being empty.*

Click the **Add** button of the Objectives dialog to open the Add Objective dialog. At the bottom of this dialog you will see a list of EM.Cube's available standard output parameters (Figure 5). The contents of this list vary depending on the observables you have already defined for your project. Since the wizard created a Port Definition for this project, you will see a number of standard output parameters related to the S/Z/Y parameters. A design objective is defined as a logical statement:

Expression_1 Operator Expression_2

The first and second expressions can be any mathematical expression involving the standard output parameters, variables, Python functions, etc. The logical operators are "==", "<", "<=", ">", ">=" and "!=" (Not Equal To). For example,

```
20*log10(S11M) == -20
```

If you set the mouse focus at one of the **Expression** boxes and then double-click on the name of one of the output parameters in the list, it will be inserted in that box. Set up the following design objective as shown in the figure 5. Click the **OK** button in the Add Objective dialog to return to the Objectives dialog. You will see your new design objective added to the current objectives list (Figure 6). Click the **OK** button and close this dialog, too, and return to the project workspace.

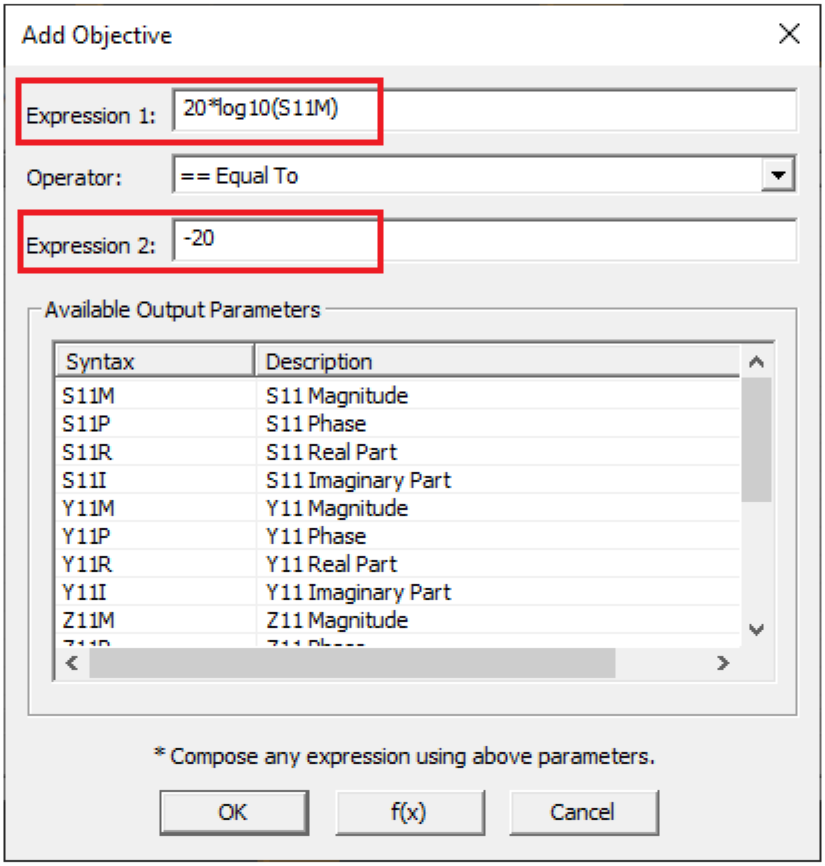


Figure 5. *Defining a new design objective in the "Add Objective" dialog.*

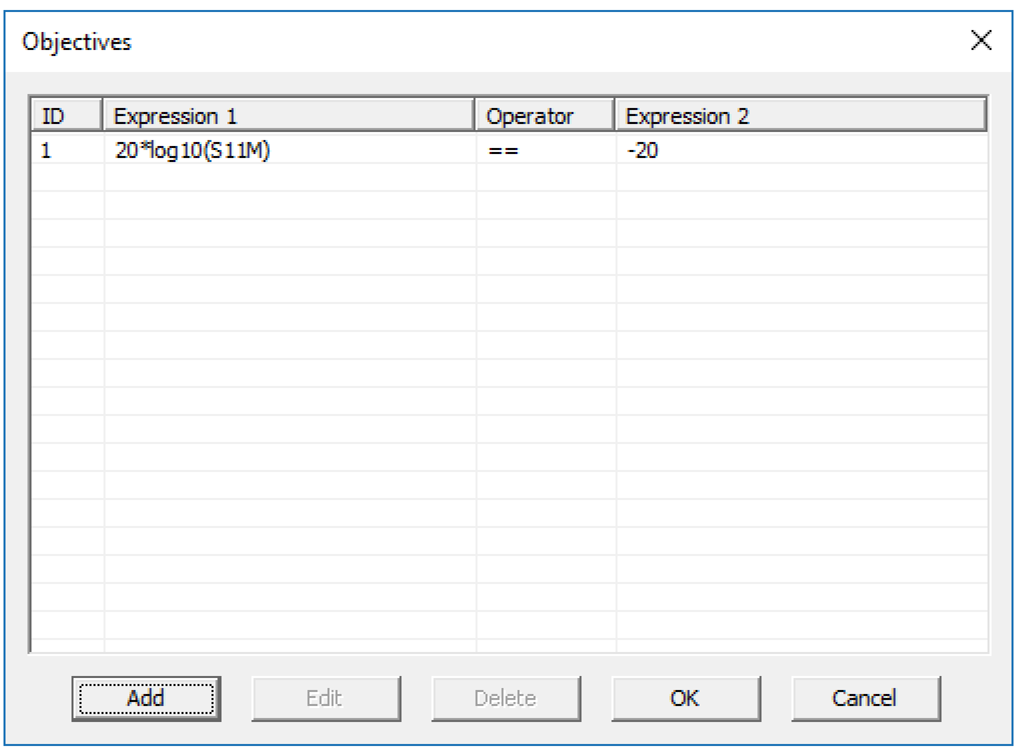


Figure 6. *EM.Cube's Objective dialog showing the newly defined design objective.*

10.5 Setting Up the Optimization Process

Open the Run Simulation dialog and select **Optimization** from the drop-down list labeled **Simulation Mode** (see Figure 7) Click the **Settings** button next to this drop-down list to open the Optimization Settings dialog.

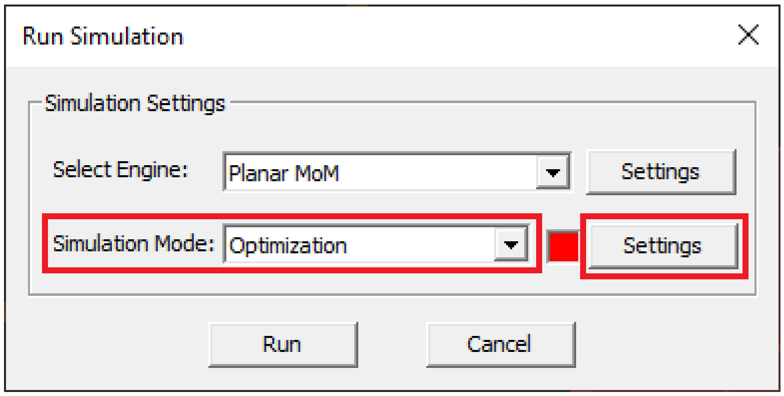


Figure 7. *Setting optimization as the simulation mode in EM.Picasso's run dialog.*

Keep the default optimization **Algorithm Type** as "Powell's Method" (Figure 8). Next, you need to define the optimization variables. Similar to the case of a Parametric Sweep, on the left side of the dialog you will see a list of all the available **Independent Variables** already defined in your project.

Select and highlight "recess_dep" and click the right arrow 

button in the middle of the dialog to move the selected variable to the **Optimization Variables** list on the right. A new dialog titled Define Optimization Variable dialog opens up. Enter 2 and 16 for the **Min Value** and **Max Value**, respectively (Figure 9). Keep the default value of 0.1 for the **Variable Precision**:

Name	recess_dep
Min Value	2
Max Value	16
Variable Precision	0.1

Repeat the same procedure for "recess_wid" and define the associated optimization parameters as the following (Figure 10):

Name	recess_wid
Min Value	1
Max Value	8
Variable Precision	0.1

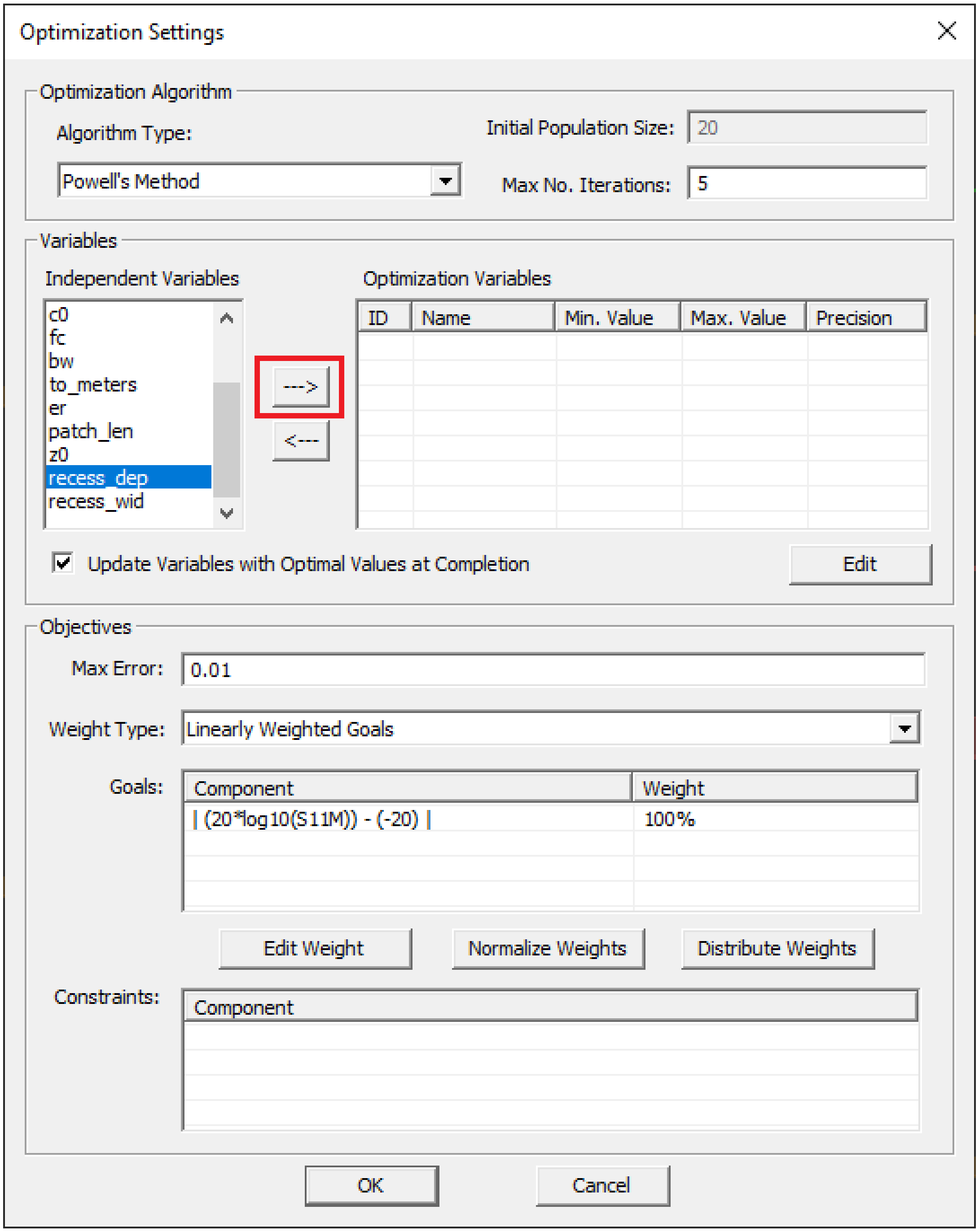


Figure 8. *EM.Picasso's Optimization Settings dialog before designating the optimization variables.*

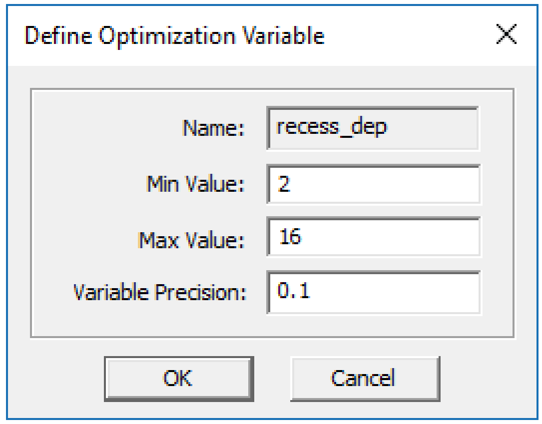


Figure 9. *Defining the bounds of the optimization variable "recess_dep".*

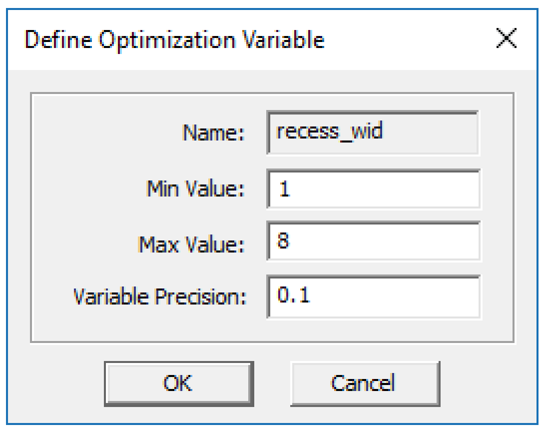


Figure 10. *Defining the bounds of the optimization variable "recess_wid".*

Back in the Optimization Settings dialog, you will see the specifications of the two optimization variables in the table on the right (Figure 11). Set the value of **Max Error** equal to 0.1. This is used for the convergence of the objective function or error function. You can see from Figure 11 that the error function or "goal" has been defined by the mathematical expression:

```
|(20*log10(S11M))-(-20)|
```

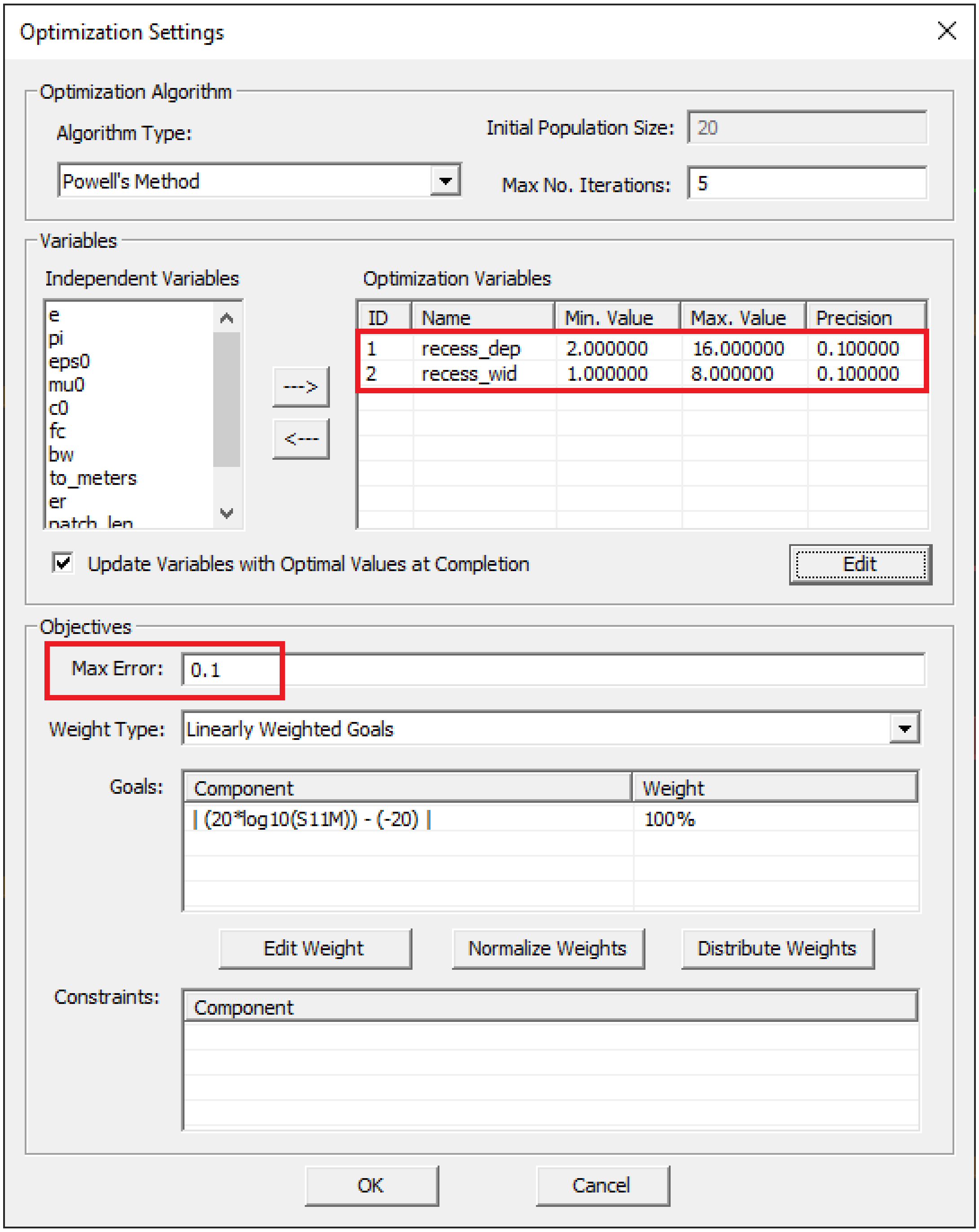
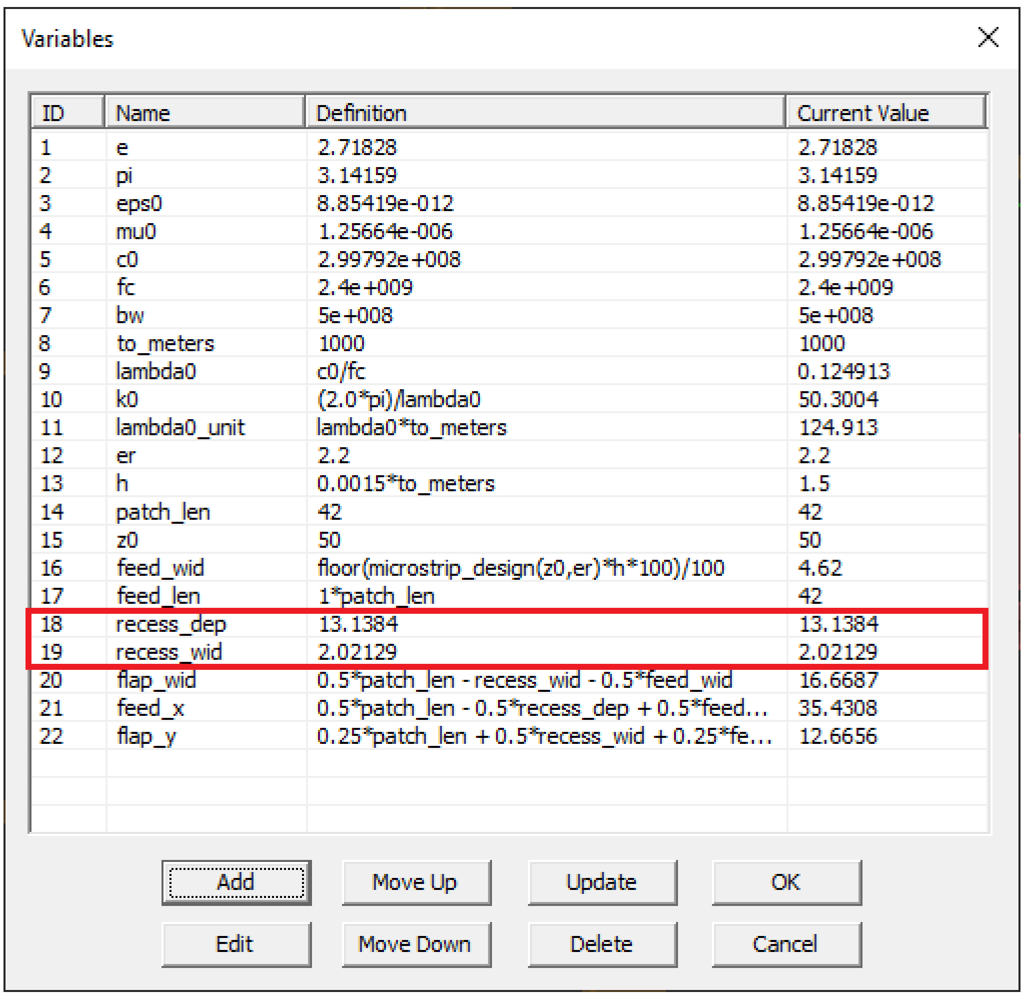


Figure 11. *The Optimization Settings dialog after designating the optimization variables.*

10.6 Running the Optimization of the Patch Antenna

Run the simulation and wait until the optimization algorithm converges. Note that sometimes the optimization process may never converge. This means that the goal you have set for your optimization might never be achieved within the defined range of the optimization variables. In that case, the optimization algorithm will complete the specified maximum number of iterations and will exit the loop. If the optimization is successful, EM.Cube automatically changes the values of the optimization variables and sets them equal to their optimal values. In this project, the Powell optimization algorithm yields the following optimal values for the designated design variables (Figure 12):

Design Variable Name	Optimal Value
recess_dep	13.1384
recess_wid	2.02129



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	2.4e+009	2.4e+009
7	bw	5e+008	5e+008
8	to_meters	1000	1000
9	lambda0	c0/fc	0.124913
10	k0	(2.0*pi)/lambda0	50.3004
11	lambda0_unit	lambda0*to_meters	124.913
12	er	2.2	2.2
13	h	0.0015*to_meters	1.5
14	patch_len	42	42
15	z0	50	50
16	feed_wid	floor(microstrip_design(z0,er)*h*100)/100	4.62
17	feed_len	1*patch_len	42
18	recess_dep	13.1384	13.1384
19	recess_wid	2.02129	2.02129
20	flap_wid	0.5*patch_len - recess_wid - 0.5*feed_wid	16.6687
21	feed_x	0.5*patch_len - 0.5*recess_dep + 0.5*feed...	35.4308
22	flap_y	0.25*patch_len + 0.5*recess_wid + 0.25*fe...	12.6656

Figure 12. *The variables dialog showing the optimal values of the design variables "recess_dep" and "recess_wid".*

Figure 13 shows the geometry of the optimized patch antenna with the recessed microstrip feed line.

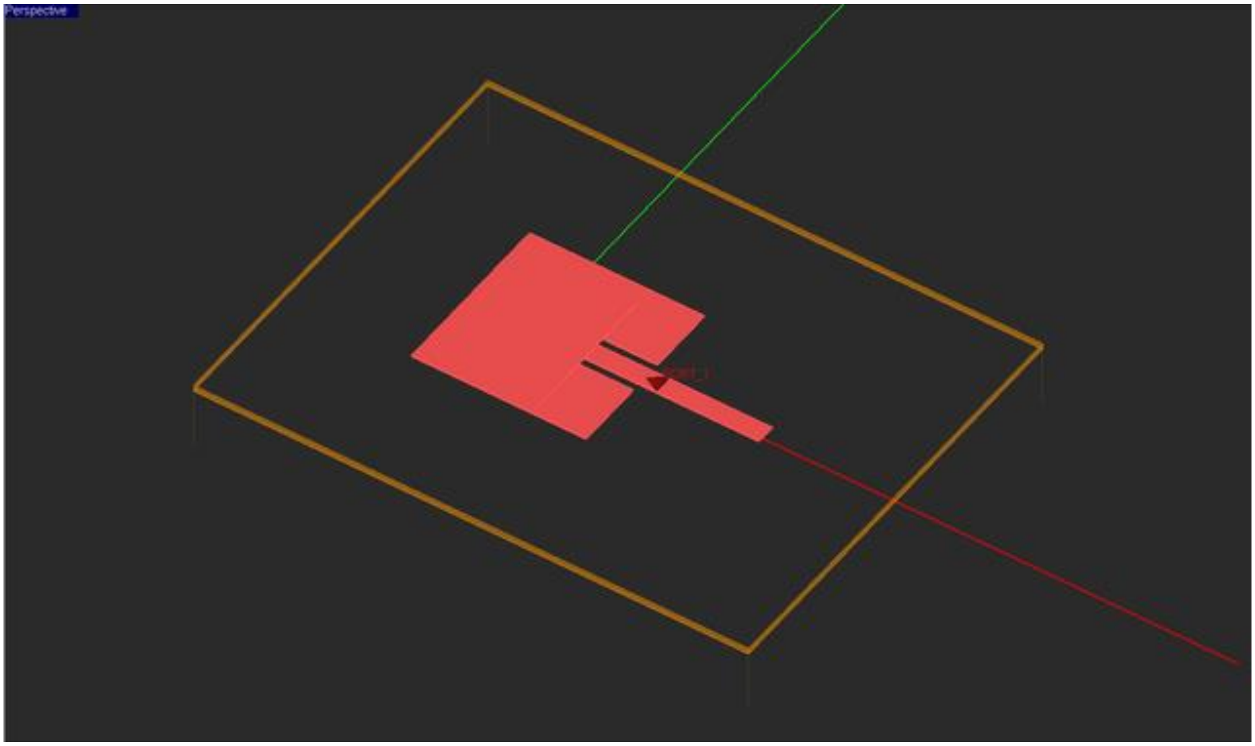


Figure 11. *The geometry of the optimized patch antenna with the recessed microstrip feed line.*

10.7 Verifying Your Optimized Patch Design

To verify the outcome of your optimization process, run a **Single-Frequency Analysis** of your patch structure at the project center frequency of $f_c = 2.4$GHz. After the completion of the simulation, the output message window reports the port characteristics of your new optimized antenna:

S11: -0.060578 -0.077976j

S11(dB): -20.109976

Z11: 43.781258 -6.894998j

Y11: 0.022288 +0.003510j

As you can see from the value of the return loss, the specified design goal has been accomplished.