Optimization of a Dual Band Slot Antenna using ANSYS® HFSS and optiSLang®

Inhaltsverzeichnis

1 Optimization of a Dual Band Slot Antenna

1.1 Introduction

The dual band slot antenna [1] is depicted in figure 1. It is designed to operate in the WLAN frequency bands of 2.4GHz and 5.8GHz.
The geometry of the conducting surfaces of the PCB is parametrized by 12 parameters:

- The width and length of the slot (*ws, ls*)
- The distances of the U-shaped conductors in the ground plane to the boundary of the slot on x- and y-direction (*gap1, gap2*)
- The distance of the two U-shaped conductors in the ground plane to each other (*dd*)
- The width of the U-shaped conductors in the ground plane in x- and y-direction (*w1, w2*)
- The length and the width of the microstrip feed line (*lf, wf*)

The goal of the simulation is to determine the return loss of the antenna in the frequency range of 1.5-7GHz. Afterwards the antenna is tuned for the given frequencies. The goal is that the minima of the return loss are at the desired frequencies and the return loss at those frequencies is minimal, but at least less than -12dB.

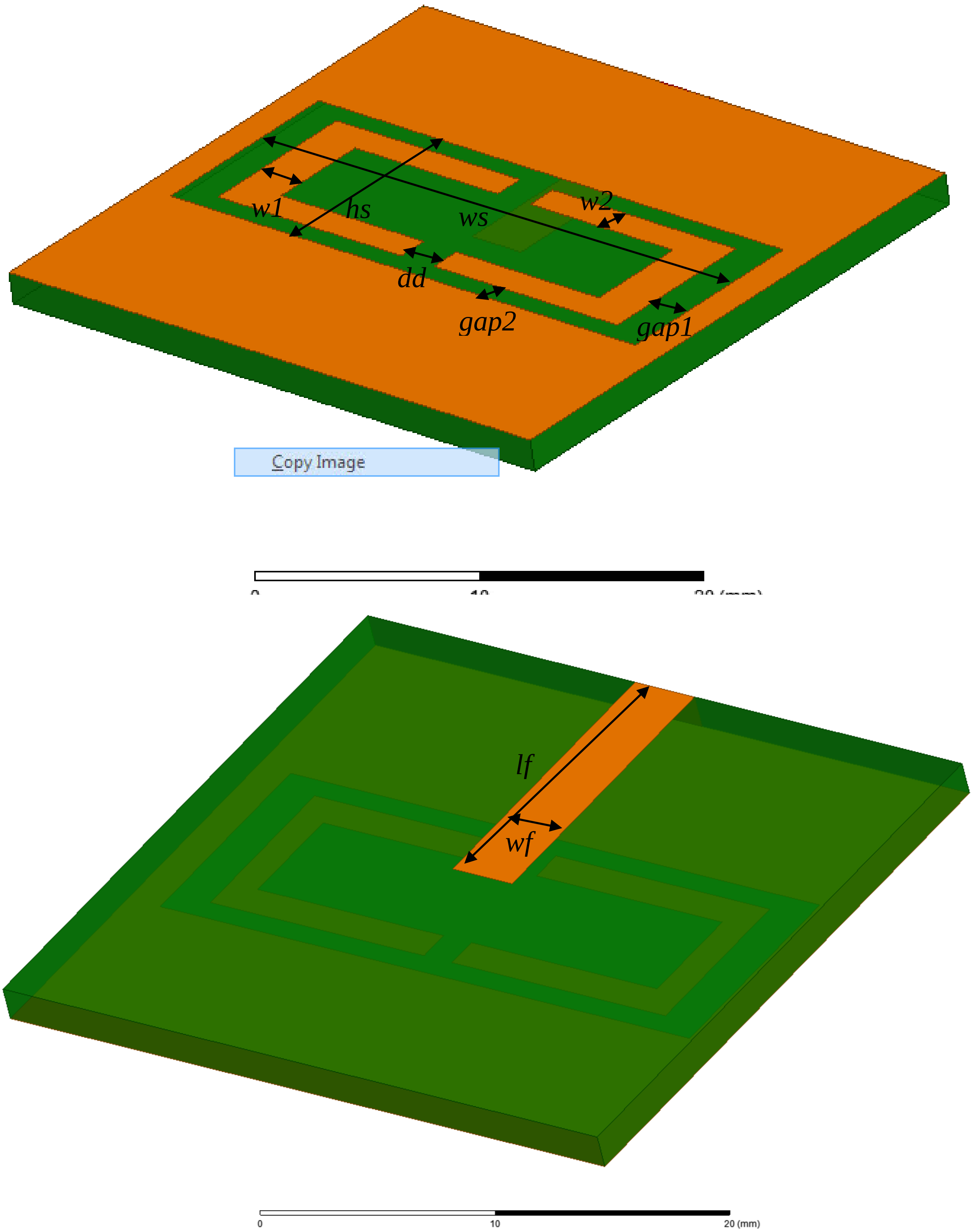


Fig. 1: Dual band slot antenna

1.2 First Steps

- Open ANSYS Workbench
- Set the Language to English: *Tools > Options… > Regional and Language Options > Language > English*
- Close ANSYS Workbench, that the language changes become active
- Open ANSYS Workbench again.
- Import the HFSS project: *File > Import… > Dual_Band_Slot_Antenna.hfss*
- Save the Workbench Project: *File > Save As… > Dual_Band_Slot_Antenna.wbpj*
- Open the HFSS component system

1.3 Setting up the Antenna Simulation

The HFSS environment is depicted in figure 2.

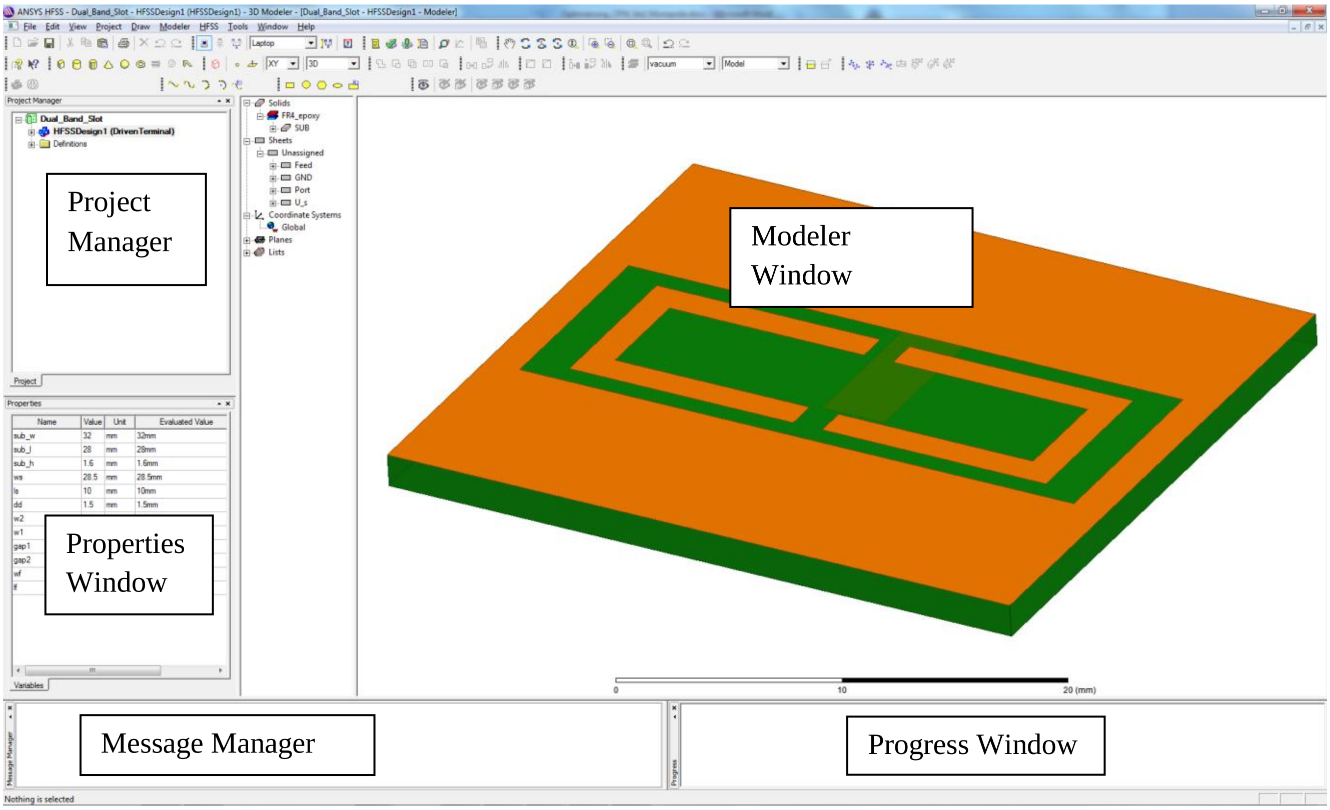


Fig. 2: The HFSS Environment

- Set the solution type to driven terminal: R*ight click on the HFSS Design in the Project Manager > Solution Type…*

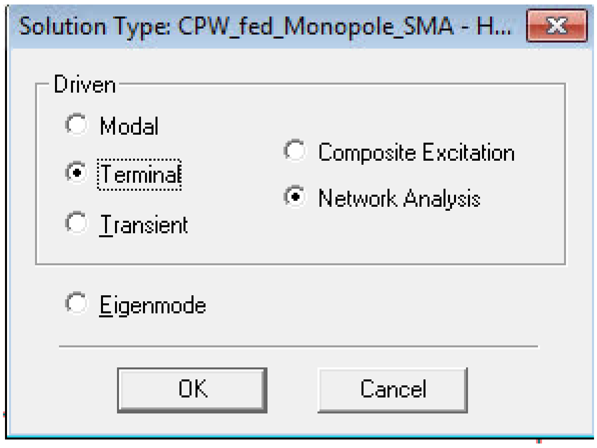
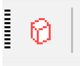


Fig. 3: Setting the Solution Type

- Create a region which is large enough for the radiation at the lower frequency (1/4 of the wave length): *Click on the red box in the tool bar and select an absolute offset of 35mm*



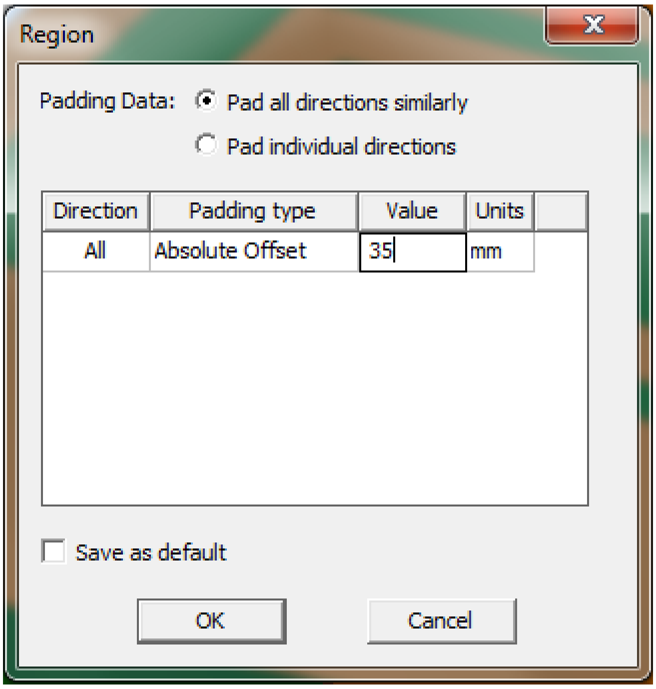


Fig. 4: Creating a Region

- Assign a radiation boundary: *Select the Air Box > Right click into the modeler window >All Object Faces > Right click into the modeler window > Assign Boundary > Radiation…*

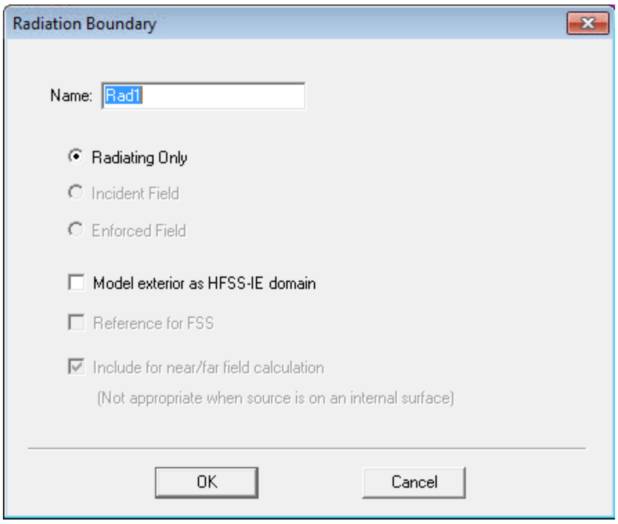


Fig. 5: Assigning Radiation Boundary Conditions

- Hide the Air Box: *Select the Air Box > Click on the Eye with the red cross in the tool bar*

Fig. 6: Hiding an Object

- Fit the antenna to the screen size: *Press 'Control' and 'D'*

- Assign a finite conductivity to all conducting surfaces on the PCB: *Select the three sheets Feed, GND and U_s > right click into the modeler window > Assign Boundary > Finite Conductivity… > Check the 'Use Material' box > push the material button > select copper*

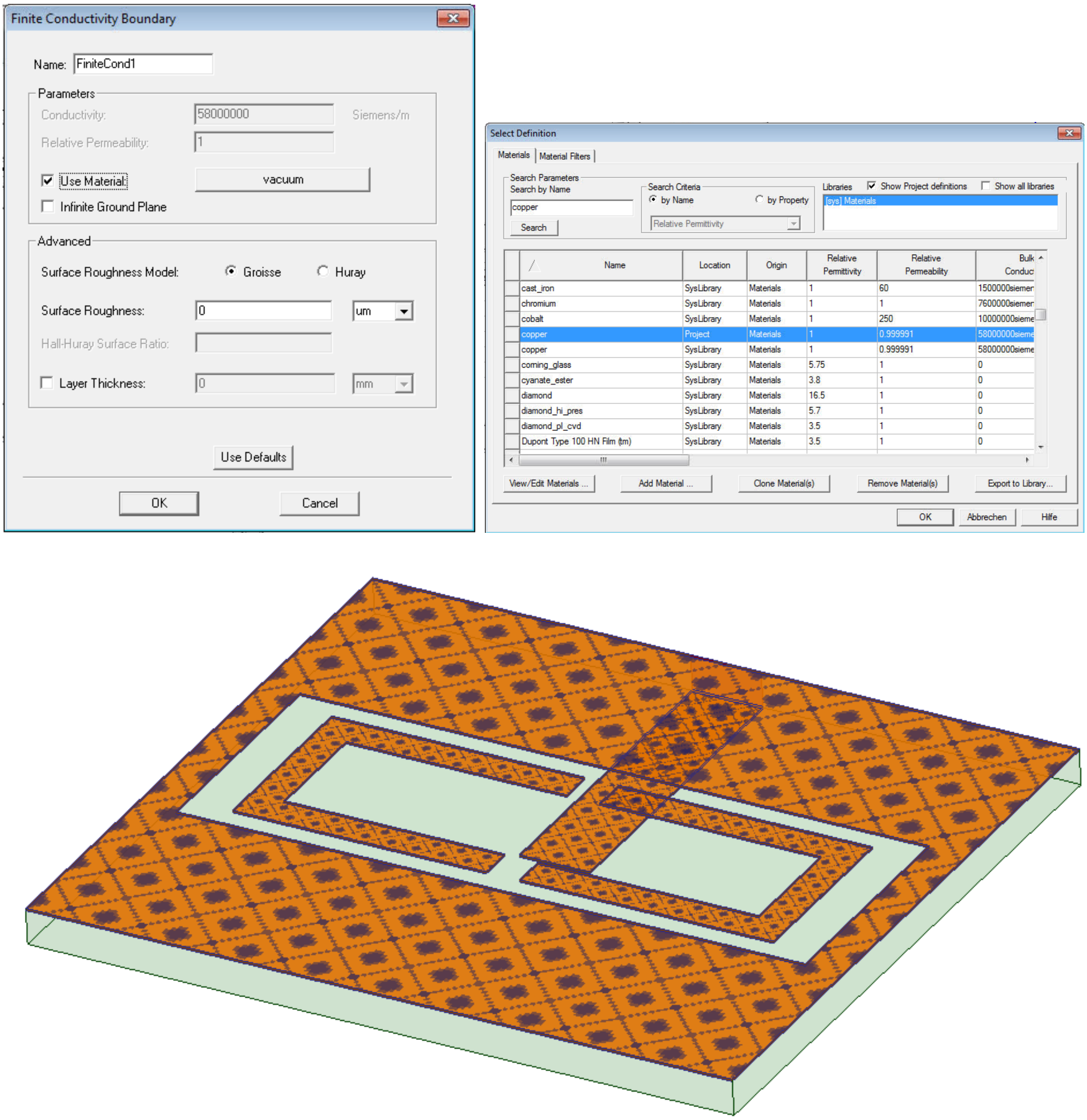


Fig. 7: Assigning Finite Conductivity to Sheets

- Assign a port excitation: *Select the red rectangular face at the side of the PCB > right click into the modeler window > Assign Excitation > Lumped Port…*

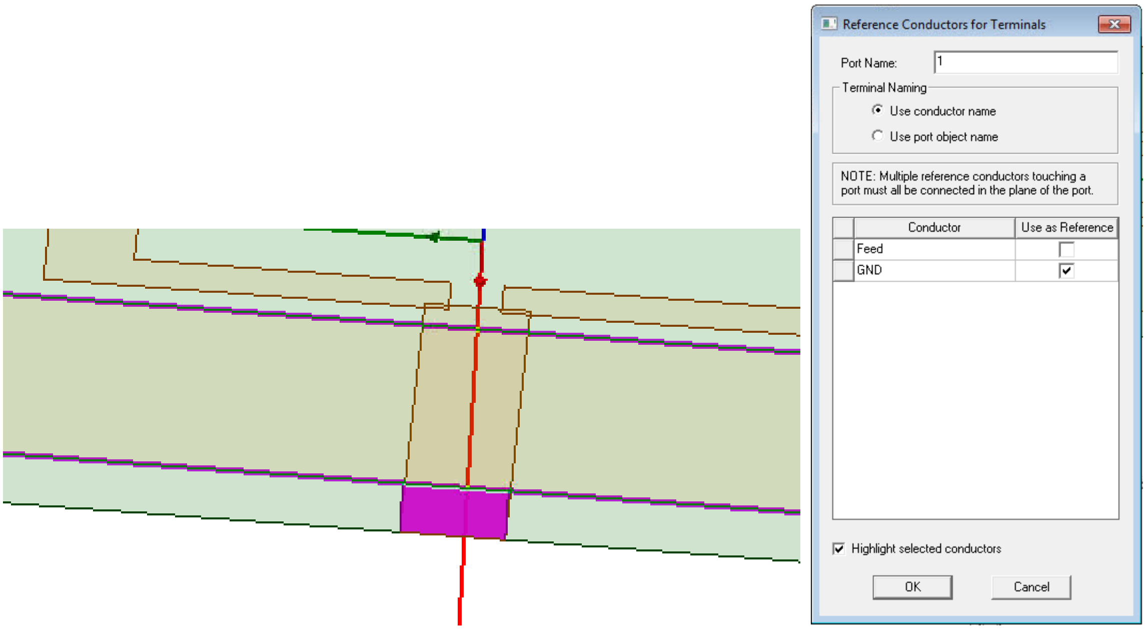


Fig. 8: Assigning the Port

- Create an analysis setup: *Right click on Analysis in the Project Manager > Add Solution Setup…*
  - *Solution Frequency: 5.8GHz*
  - *Maximum Number of Passes: 20*
  - *Rename the setup to Setup_58 by slowly clicking twice on the setup in the Project Manager and entering the name.*

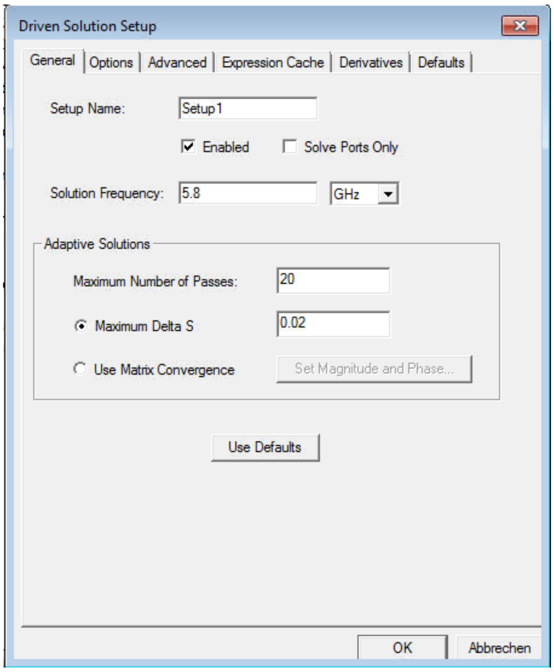


Fig. 9: Solution Setup for 5.8GHz

- Create a second analysis setup: *Right click on Analysis in the Project Manager > Add Solution Setup…*
    - *Solution Frequency: 2.4GHz*
    - *Maximum Number of Passes: 20*
    - *In the Advanced Tab check Import Mesh and click Setup Link…*
    - *Choose the solution Setup_58*
    - *Accept the variable mapping warning*
    - *Rename the setup to Setup_24*

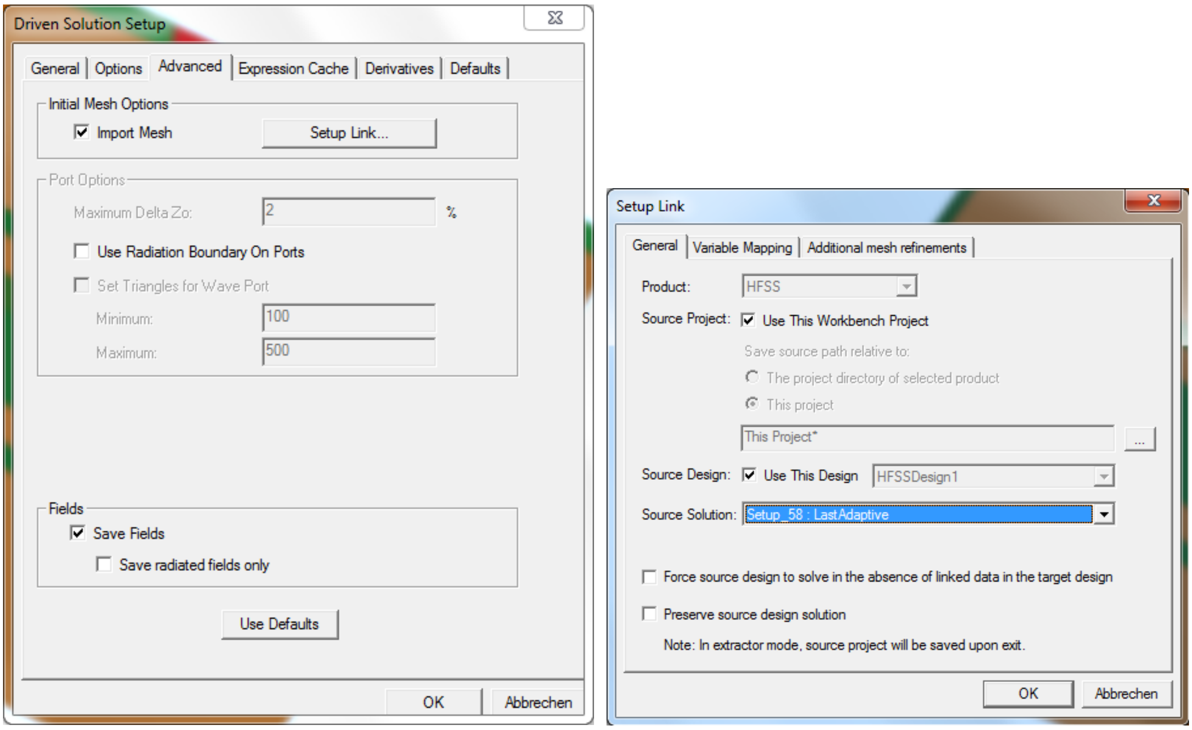


Fig. 10: Solution Setup for 2.4GHz

- Add a frequency sweep: *Right click onto Setup_24 > Add Frequency Sweep…*
    - *Sweep Type: Interpolating*
    - *Start: 1.5GHz*
    - *Stop: 7GHz*
    - *Step Size: 0.01GHz*

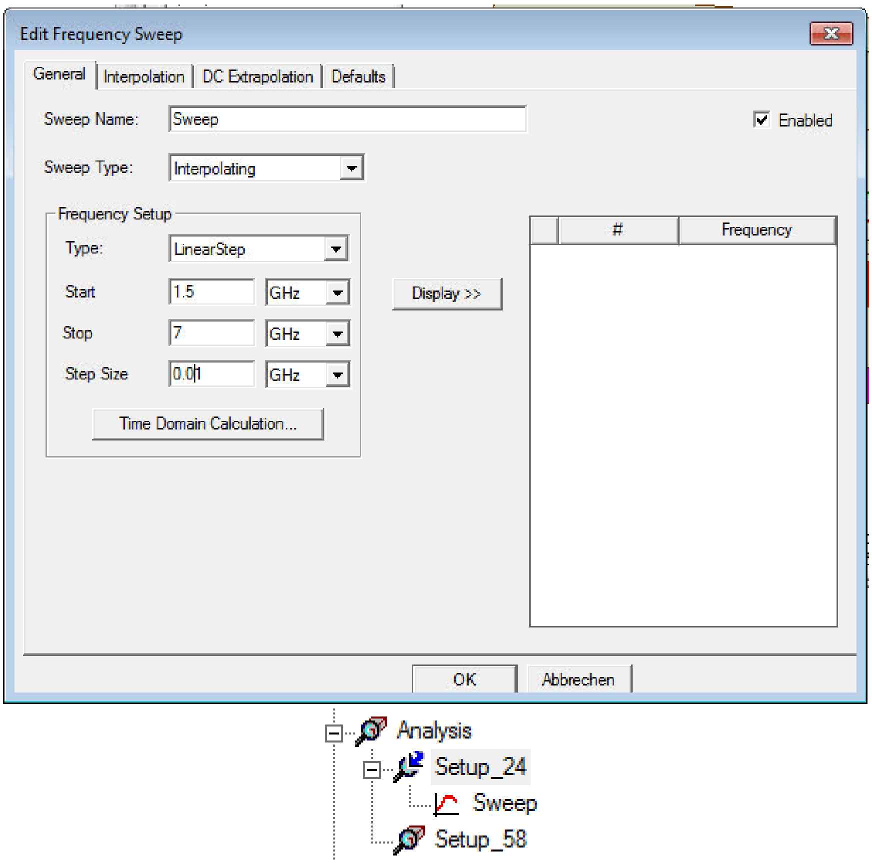


Fig. 11: Frequency Sweep

- Adjust the solver options to use 4 cores for the job: *Tools > Options > HFSS Options… > Solver Tab*

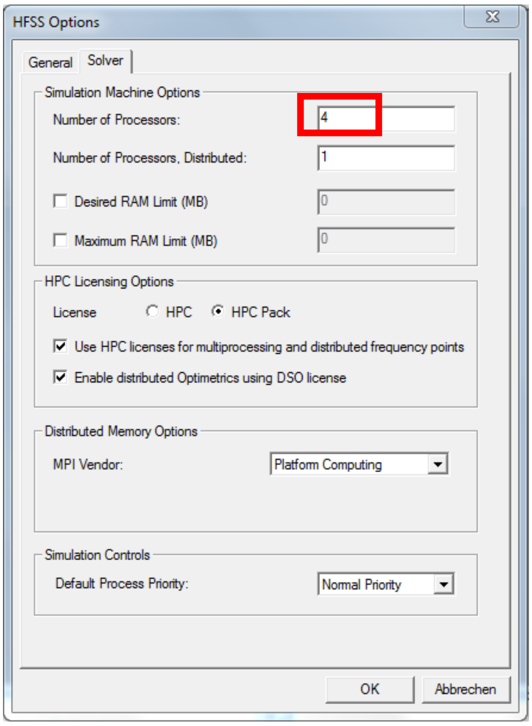


Fig. 12: Solver Options

- Save the Workbench project
- Check the simulation model: *Click on the green checkmark in the tool bar*

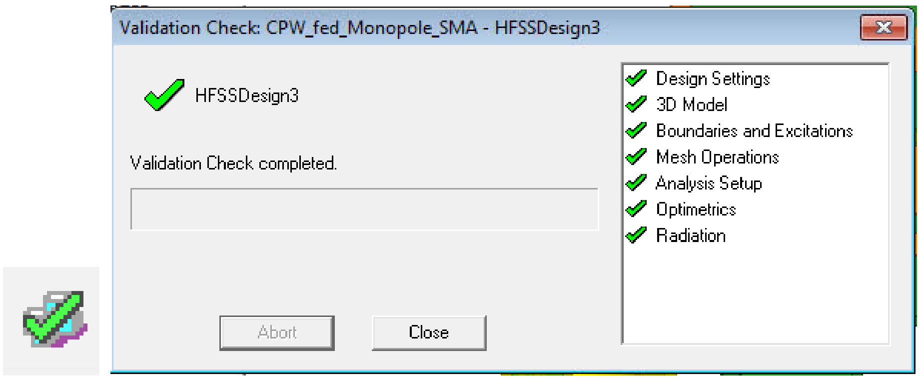


Fig. 13: Model Check

- Solve the model: *Right click on Setup1 in the project manager > Analyze*

- Observe the progress: *Check the progress window > Right click on the Setup1 in the project manager > Convergence…*

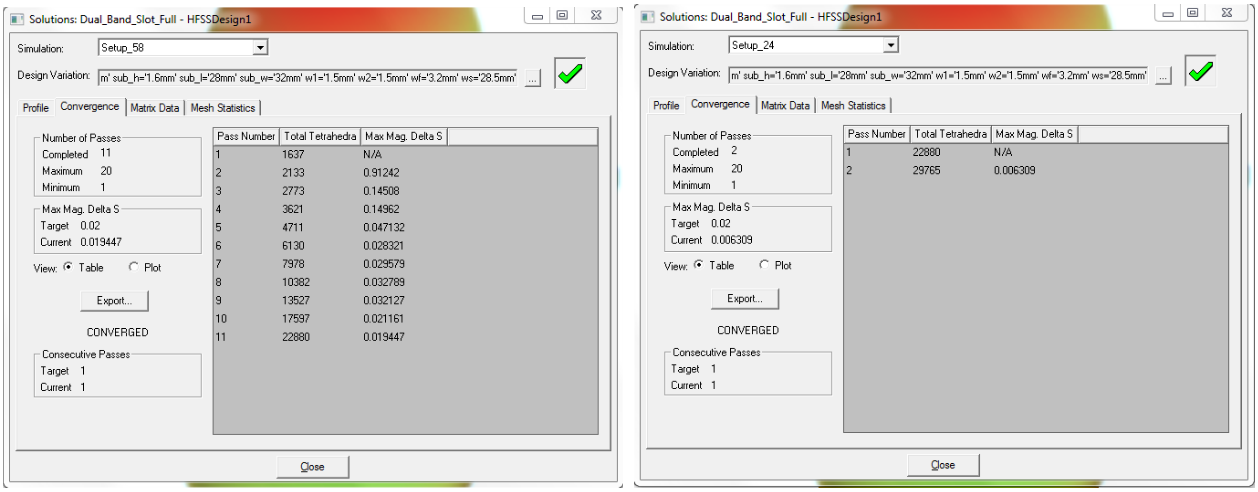


Fig. 14: Convergence

- What can be implied from the convergence of Setup_24?
- Plot the Return Loss: *Right click on Results in the project manager > Create Terminal Solution Data Report > Rectangular Plot*
    - *Solution: Setup1:Sweep*
    - *Domain: Sweep*
    - *Terminal S Parameter > St(inner_T1,inner_T1) > dB*

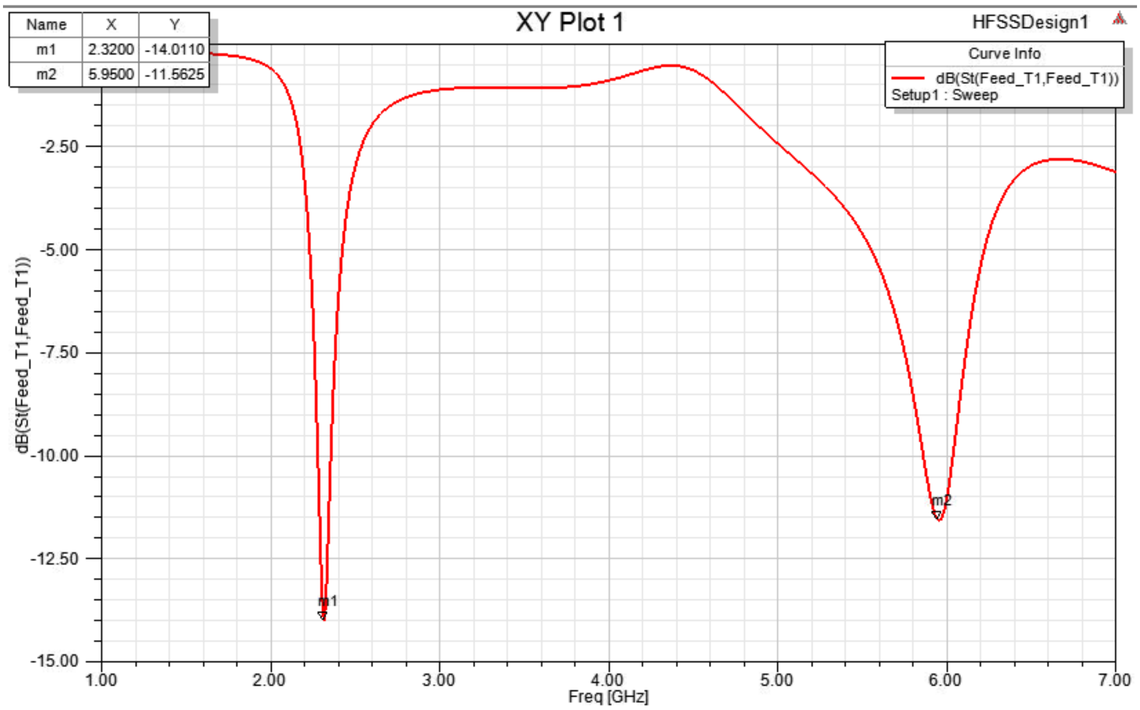


Fig. 15: Return Loss

- What are the implications of this return loss curve?

- Plot the mesh and observe, where it got refined: *Select all Objects by pressing 'Control' + 'A' > Right click into the modeler window > Plot Mesh*

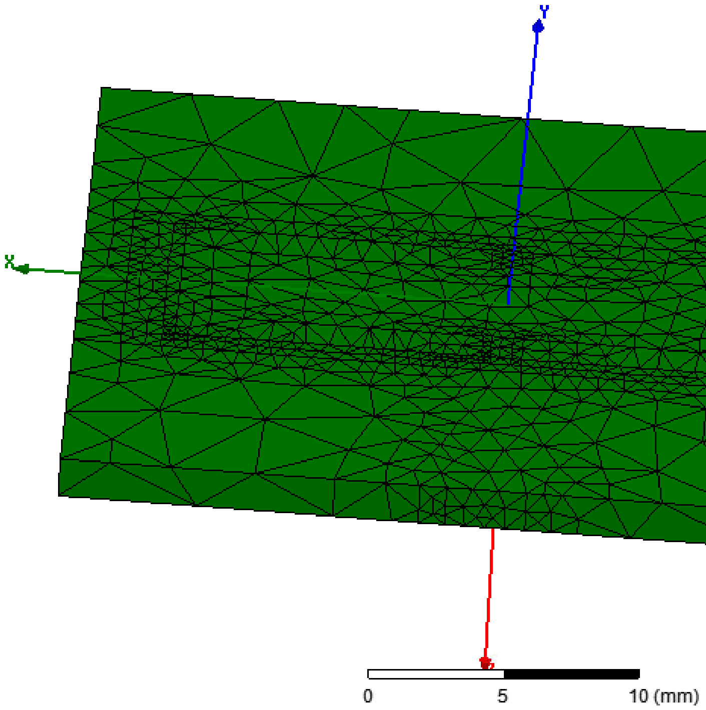


Fig. 16: Mesh

- Why did the mesh get refined at the edges of the metal?
- Plot the currents and animate them: *Select all Objects by pressing 'Control' + 'A' > Right click into the modeler window > Plot Fields > J > Mag_Jsurf*

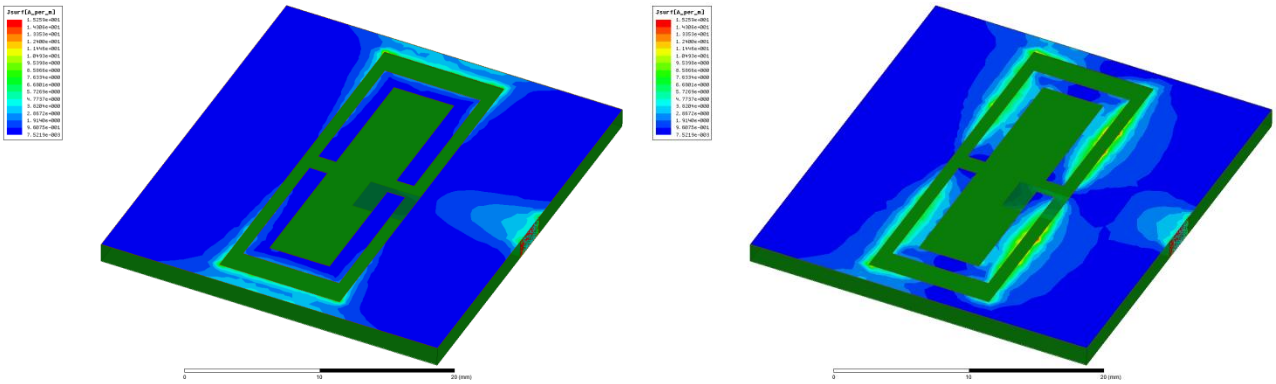


Fig. 17: Currents

- Compare the currents for the two frequencies of interest. Why are the current distributions so different?

-	Insert far field setup: *Right click onto Radiation in the project manager > Insert Far Field Setup > Infinite Sphere…*

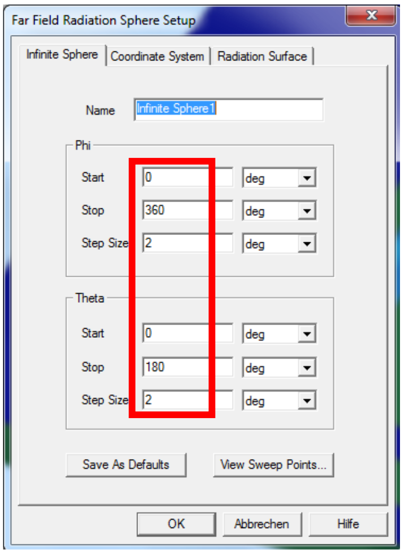


Fig. 18: Far Field Setup

-	Plot the far field patterns: *Right click onto Results in the project manager > Create Far Fields Report > 3D Polar Plot*
	- *Solution: Setup_24 resp Setup_58:LastAdaptive*
	- *Geometry: Infinite Sphere1*
	- *Gain > GainTotal > <none>*

- Attatch the radiation pattern to the geometry: *Double click onto HFSSDesign1 in the project manager > right click into the modeler window > Plot Fields > Radiation Field…*
  - *Check Visible*
  - *Scale: 0.20*

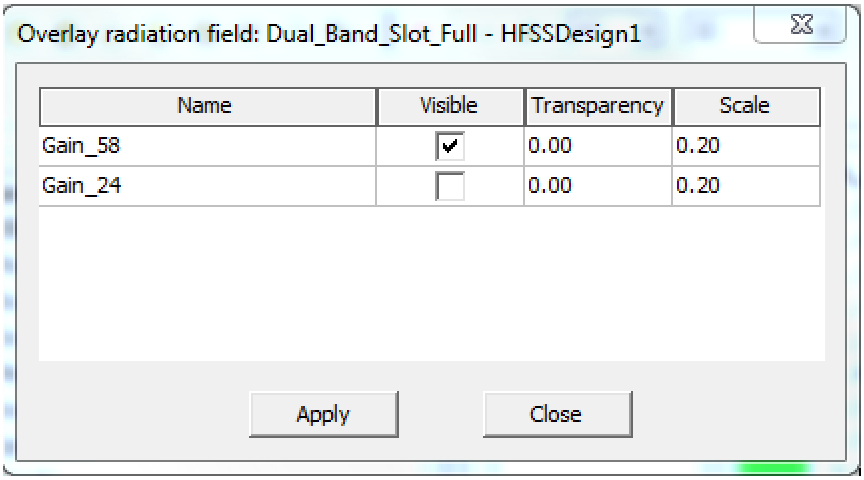


Fig. 19: Radiation Field Dialog

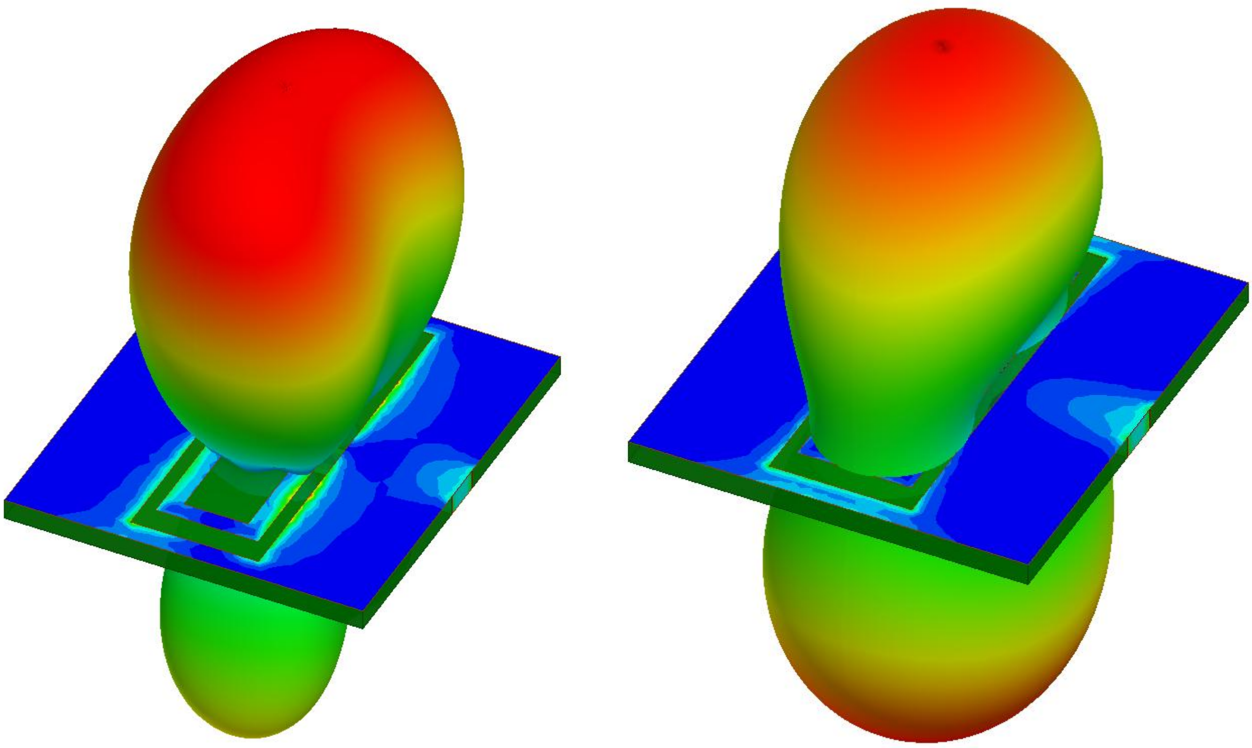


Fig. 20: Far Field

1.4 Adjusting the HFSS Setup for Optimization and Handing down the Parameters to the Workbench

In order to do an optimization of the current antenna design with optiSLang inside Workbench the HFSS Setup needs to be modified for fast calculational time and the geometry parameters of HFSS as well as the results of interest for optimization need to be handed down to the parameter manager in Workbench.

- For quick calculation times remove the far field plots and the field plots from the Project
- Uncheck the save fields in the Setup_58

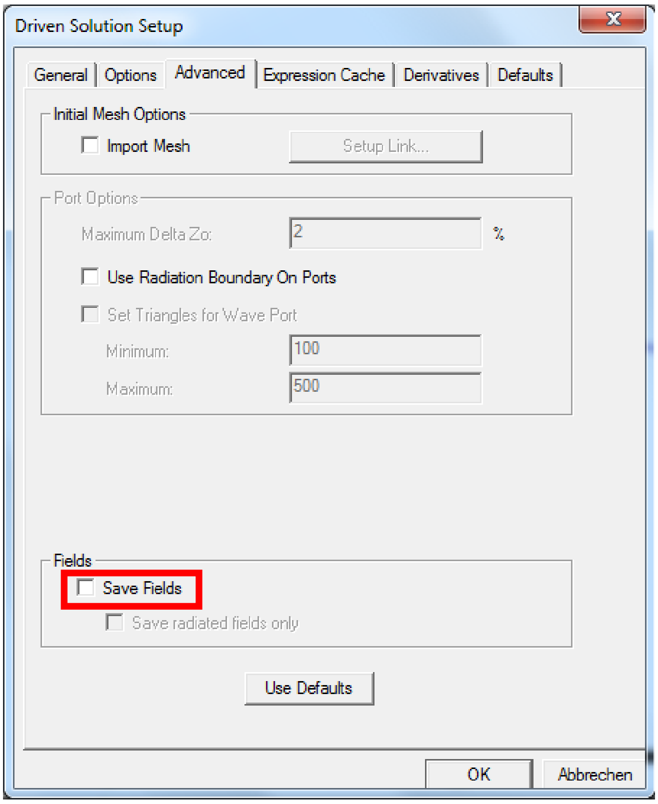


Fig. 21: Do not Save Fields

- Since the refinement at 2.4GHz was not necessary, remove the Setup_24 and add a discrete frequency sweep with the single frequency of 2.4GHz to the Setup_58.

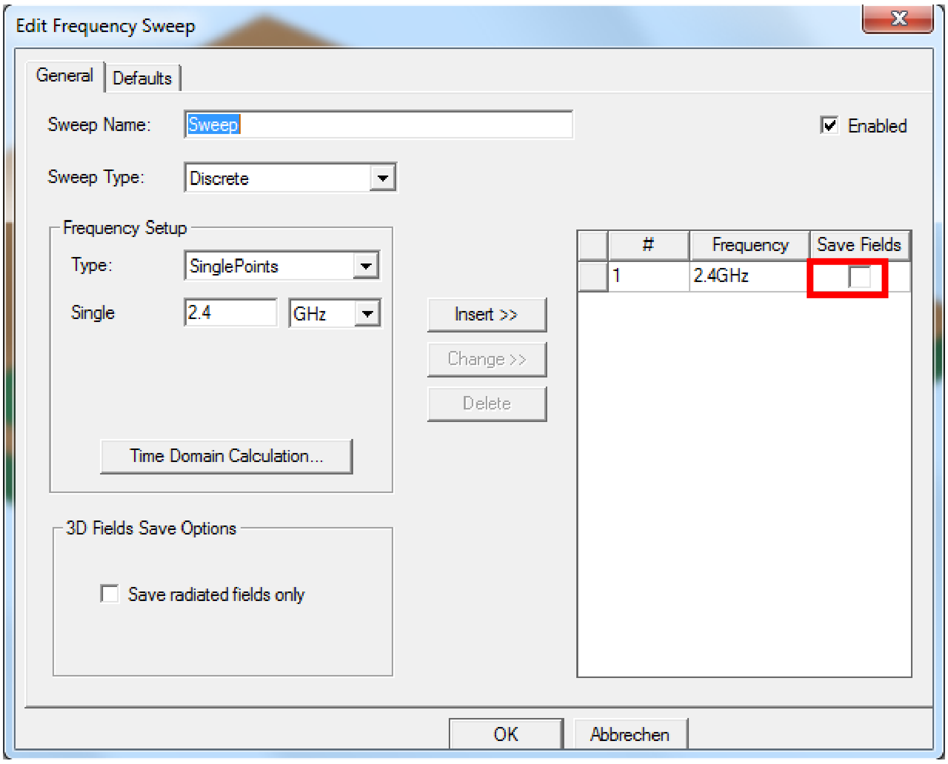


Fig. 22: Additional Frequency Point

- Set up the parameter link to Workbench: *Double click onto DefaultDesignXplorerSetup under Optimetrics in the project manager > check the parameters that should be varied (dd, gap1, gap2, lf, ls, w1, w2, wf, ws)*

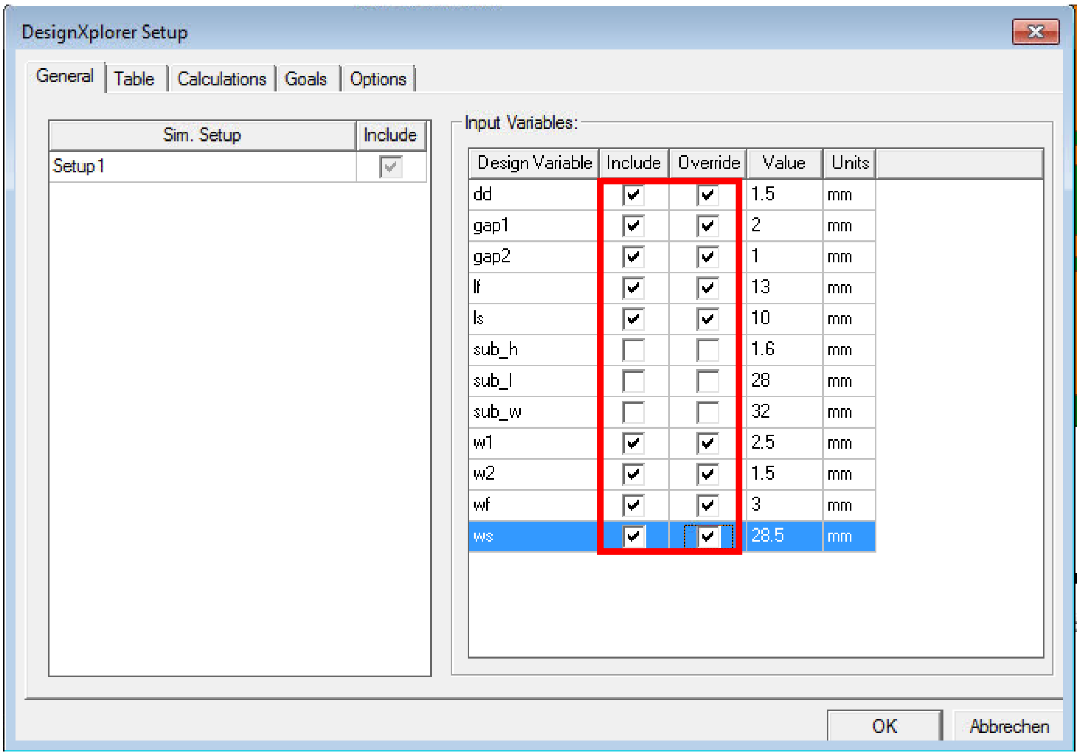


Fig. 23: DesignXplorer Setup Dialog

- Set up the results that are handed to the workbench:
  - *select the Calculations tab > Setup Calculations…*
  - *For Solution select 'Setup_58 : Last Adaptive' > Select the Terminal S Parameter St(Feed_T1,Feed_T1) in dB > Add Calculation.*
  - *For Solution select 'Setup_58 : Sweep' > Select the Terminal S Parameter St(Feed_T1,Feed_T1) in dB > Add Calculation.*

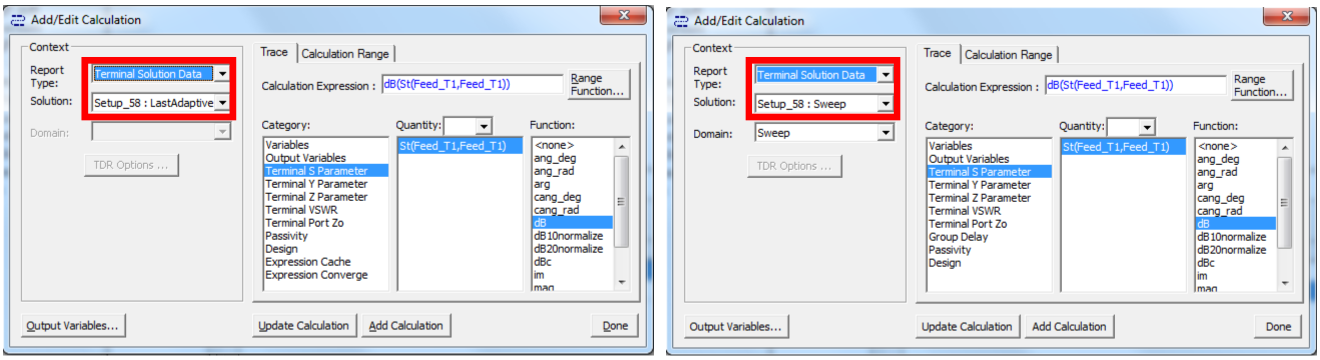


Fig. 24: Calculation Dialog

- Name the four calculations appropriately:

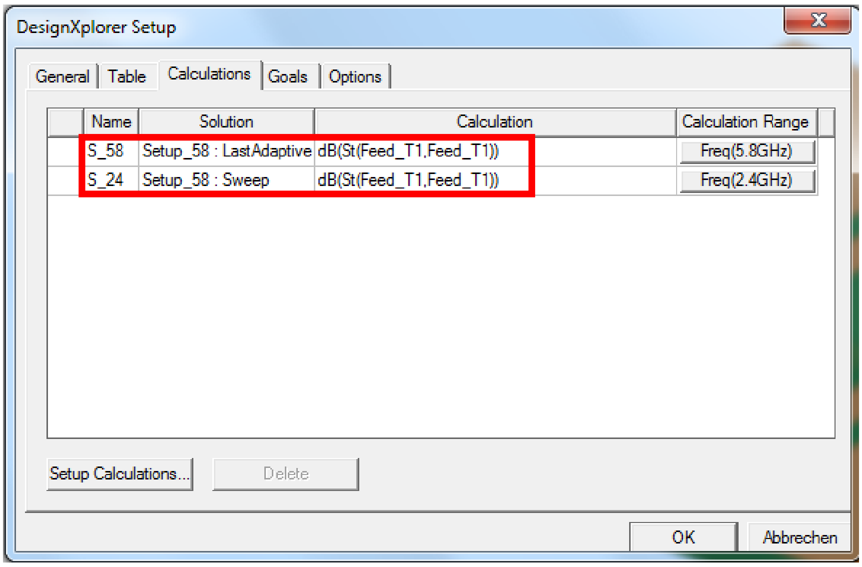


Fig. 25: Calculations

1.5 Optimization

The antenna optimization can now be done using optiSLang inside Workbench. The optimization setup includes specifying the parameter ranges, the cost function, constraints and the optimization algorithm.

- Add an optimization setup: *Drag a Optimization from the optiSLang Toolbox below the Parameter Set*

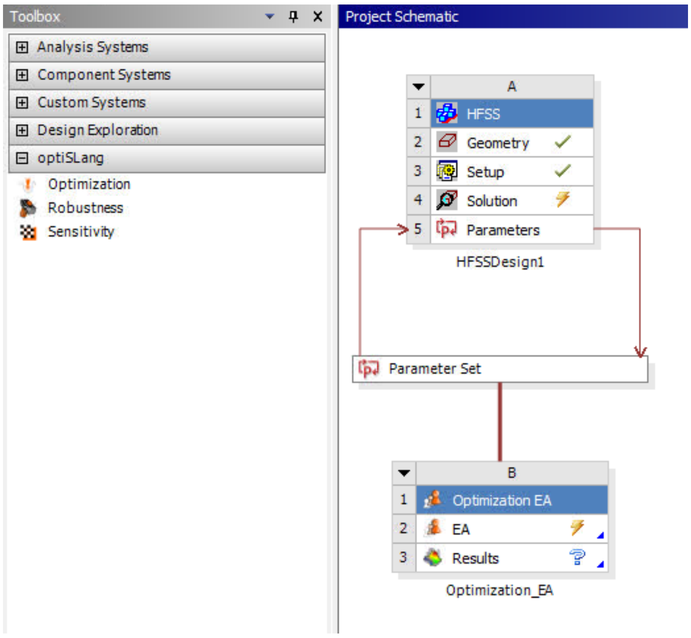
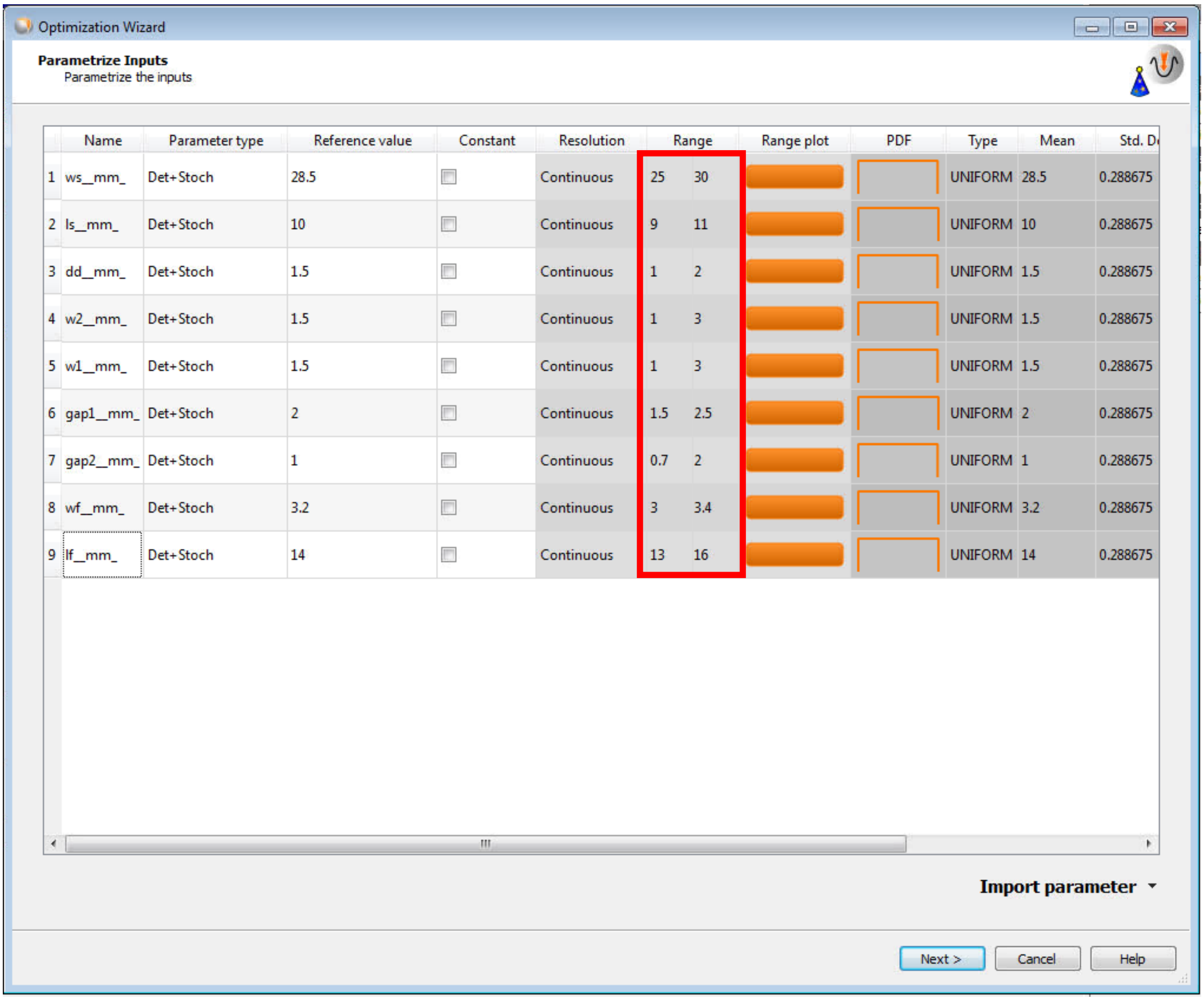


Fig. 27: optiSLang Inside Workbench

- Follow through the optimization setup wizard:
    - Enter the Parameter Ranges as follows:



	Name	Parameter type	Reference value	Constant	Resolution	Range		Range plot	PDF	Type	Mean	Std. D
1	ws_mm_	Det+Stoch	28.5		Continuous	25	30			UNIFORM	28.5	0.288675
2	ls_mm_	Det+Stoch	10		Continuous	9	11			UNIFORM	10	0.288675
3	dd_mm_	Det+Stoch	1.5		Continuous	1	2			UNIFORM	1.5	0.288675
4	w2_mm_	Det+Stoch	1.5		Continuous	1	3			UNIFORM	1.5	0.288675
5	w1_mm_	Det+Stoch	1.5		Continuous	1	3			UNIFORM	1.5	0.288675
6	gap1_mm_	Det+Stoch	2		Continuous	1.5	2.5			UNIFORM	2	0.288675
7	gap2_mm_	Det+Stoch	1		Continuous	0.7	2			UNIFORM	1	0.288675
8	wf_mm_	Det+Stoch	3.2		Continuous	3	3.4			UNIFORM	3.2	0.288675
9	lf_mm_	Det+Stoch	14		Continuous	13	16			UNIFORM	14	0.288675

Fig. 28: Optimization Setup

- Enter the cost function: max([S_24,S_58]):

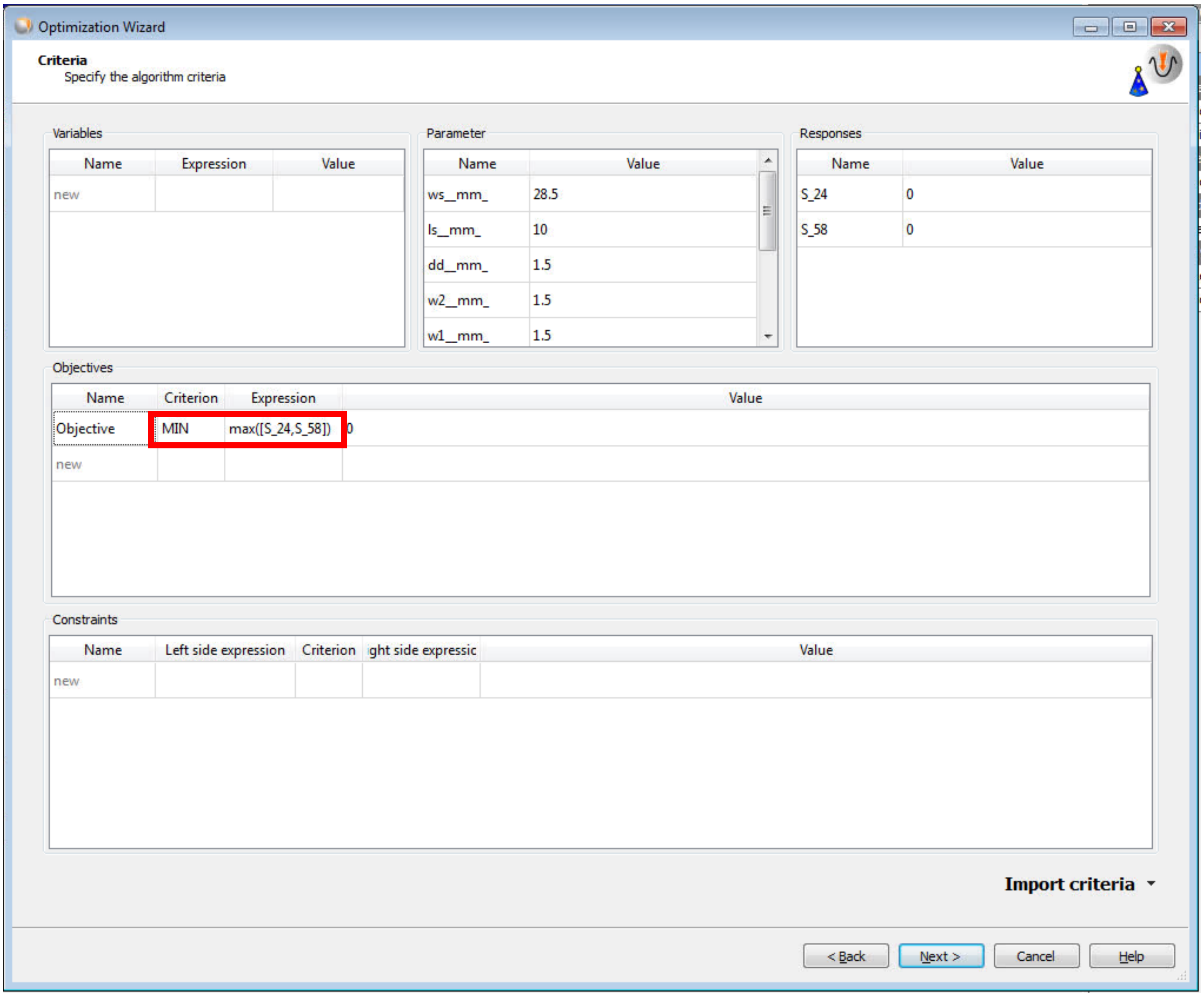


Fig. 29: Optimization Setup

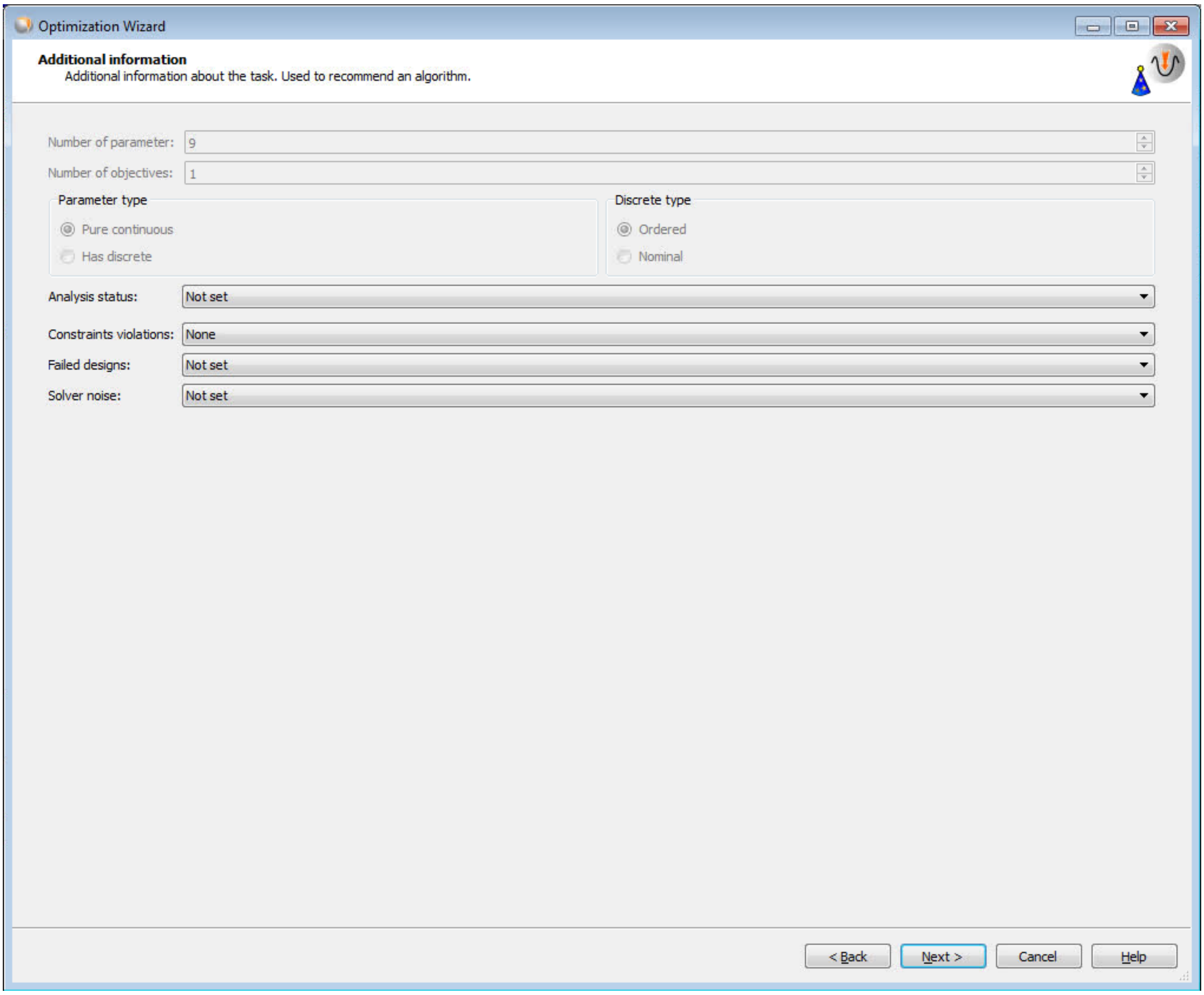


Fig. 30: Optimization Setup

- Choose the evolutionary algorithm as optimization algorithm:

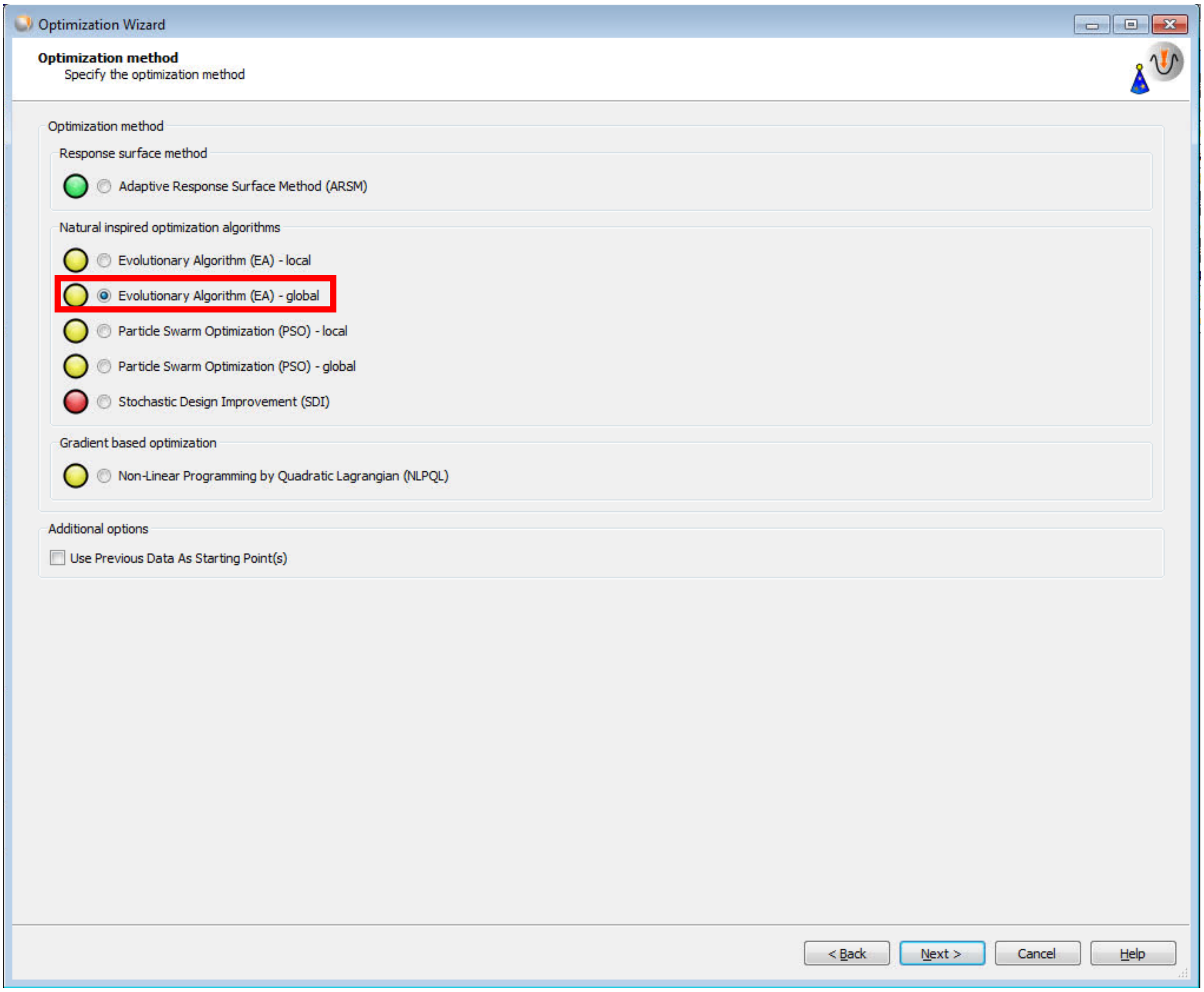


Fig. 31: Optimization Setup

- Choose the maximum number of generations to be 6:

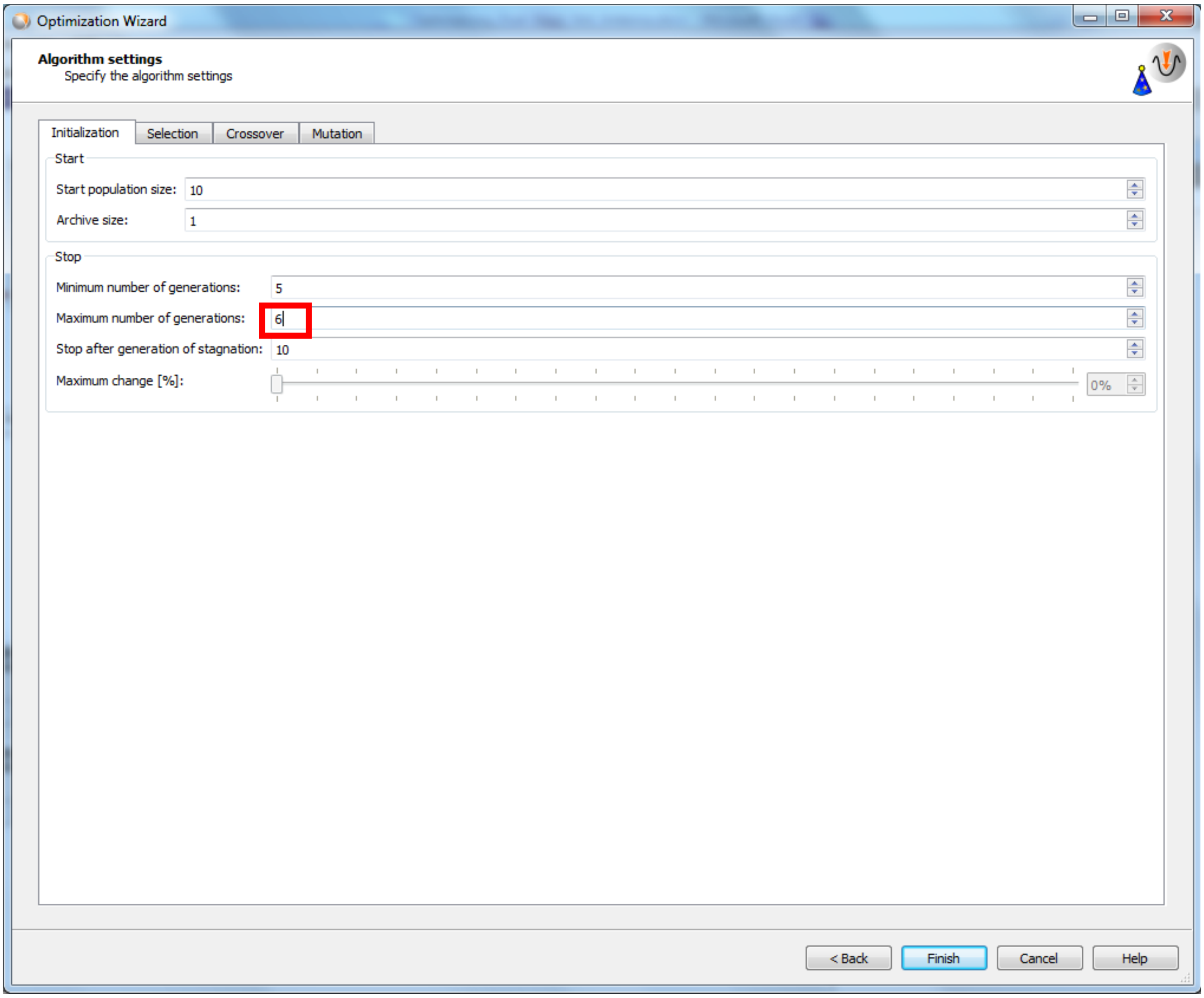


Fig. 32: Optimization Setup

- Adjust the settings inside workbench for distributed solving using RSM
- Start the optimization: *press Update Project in the Workbench*

- You can observe the designs by double clicking on Parameter Set

Table of Design Points

	F	G	H	I	J	K	L	M	N
1	P5 - w1 [mm]	P6 - gap1 [mm]	P7 - gap2 [mm]	P8 - wf [mm]	P9 - lf [mm]	P10 - S_58	P11 - S_24	Exported	Note
17	1.0463	2.4724	1.6052	3.1188	14.929	-10.353	-3.3419		Optimization_EA -- Design #15
18	1.4315	1.6049	1.2784	3.0669	13.946	-2.925	-4.018		Optimization_EA -- Design #16
19	2.5435	1.9556	1.9364	3.3356	14.552	-17.28	-10.113		Optimization_EA -- Design #17
20	1.5	2.3001	1	3.288	15.397	-11.49	-2.4433		Optimization_EA -- Design #18
21	2.9695	1.5409	1.1634	3.0564	14.943	-8.1042	-6.5808		Optimization_EA -- Design #19
22	1.1179	2.0409	1.9758	3.004	15.377	-4.7729	-4.4247		Optimization_EA -- Design #20
23	1.1688	1.9556	1.9364	3.3356	15.374	-10.923	-1.9989		Optimization_EA -- Design #21
24	2.5435	1.7404	1.2784	3.0669	14.552	-4.1901	-6.201		Optimization_EA -- Design #22
25	1.0614	2.3532	1.9364	3.1614	13.843	-5.7281	-1.0043		Optimization_EA -- Design #23
26	1.6411	1.7152	1.356	3.0426	15.781	-6.4741	-7.9152		Optimization_EA -- Design #24
27	1.6856	1.7159	1.2784	3.0951	14.009	-11.32	-7.4362		Optimization_EA -- Design #25
28	1.0112	1.7159	1.2784	3.0669	13.946	-9.5707	-19.289		Optimization_EA -- Design #26
29	1.1179	2.0409	1.9758	3.0564	15.377	-13.71	-12.612		Optimization_EA -- Design #27
30	2.9695	1.5409	1.1634	3.004	14.943	-4.1864	-2.6326		Optimization_EA -- Design #28
31	1.1688	2.4	1.2218	3.0669	16	-12.315	-7.7686		Optimization_EA -- Design #29
32	2.6459	1.7404	1.2784	3.2561	14.983	-22.259	-5.621		Optimization_EA -- Design #30
33	1.019	1.7152	1.2784	3.0661	13.946				Optimization_EA -- Design #31

Fig. 33: Design Points and Results

- After ten designs the optiSLang window pops up showing the progress of the optimization.

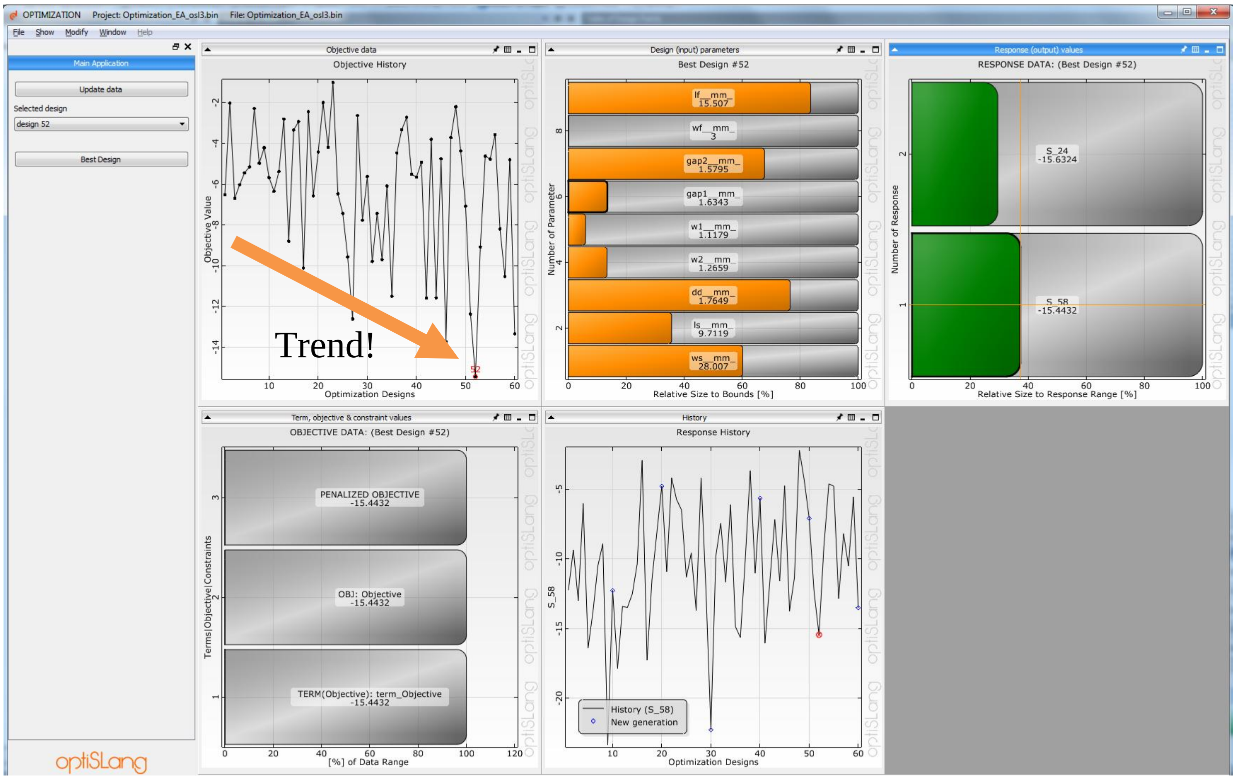


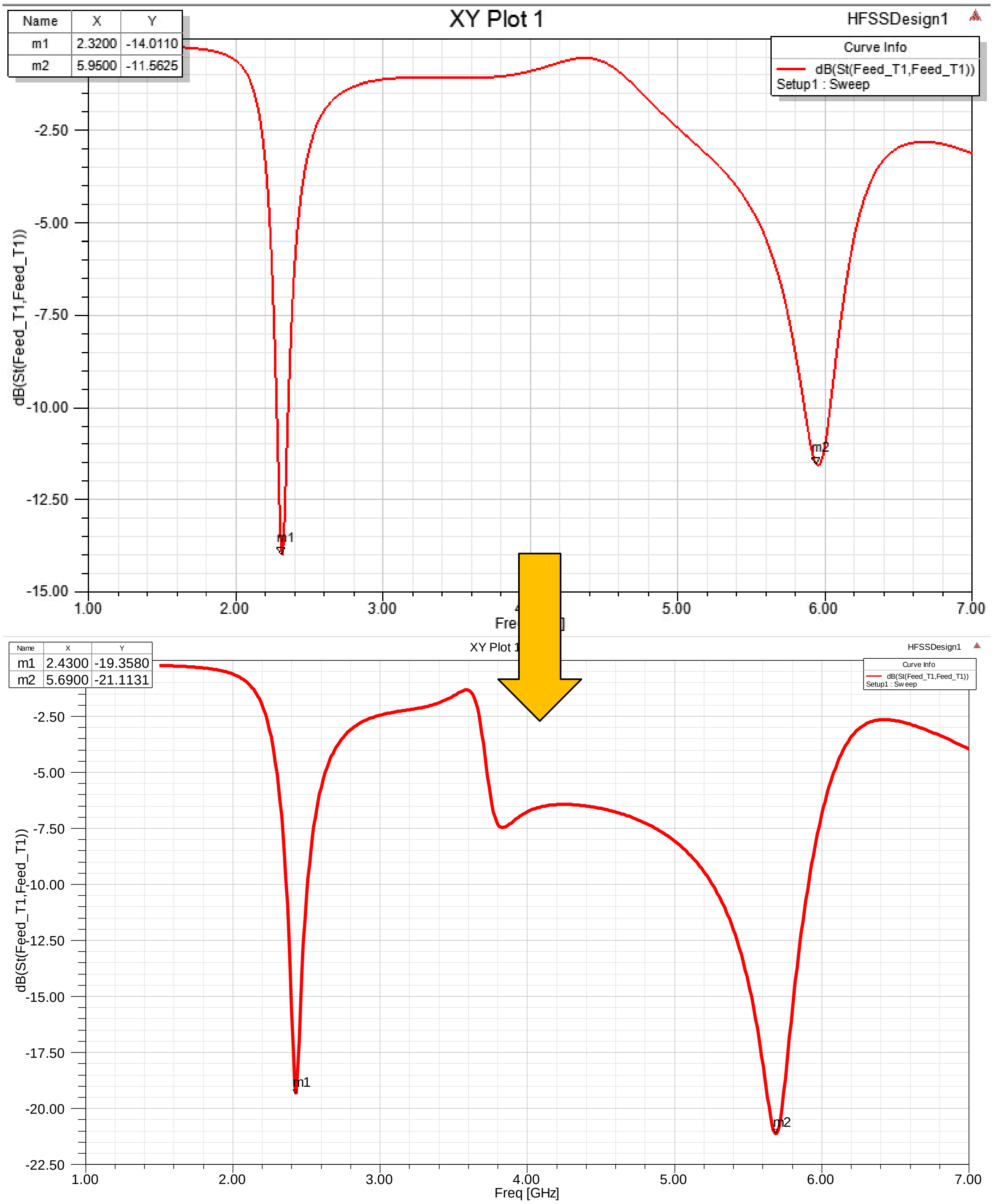
Fig. 34: Optimization Results

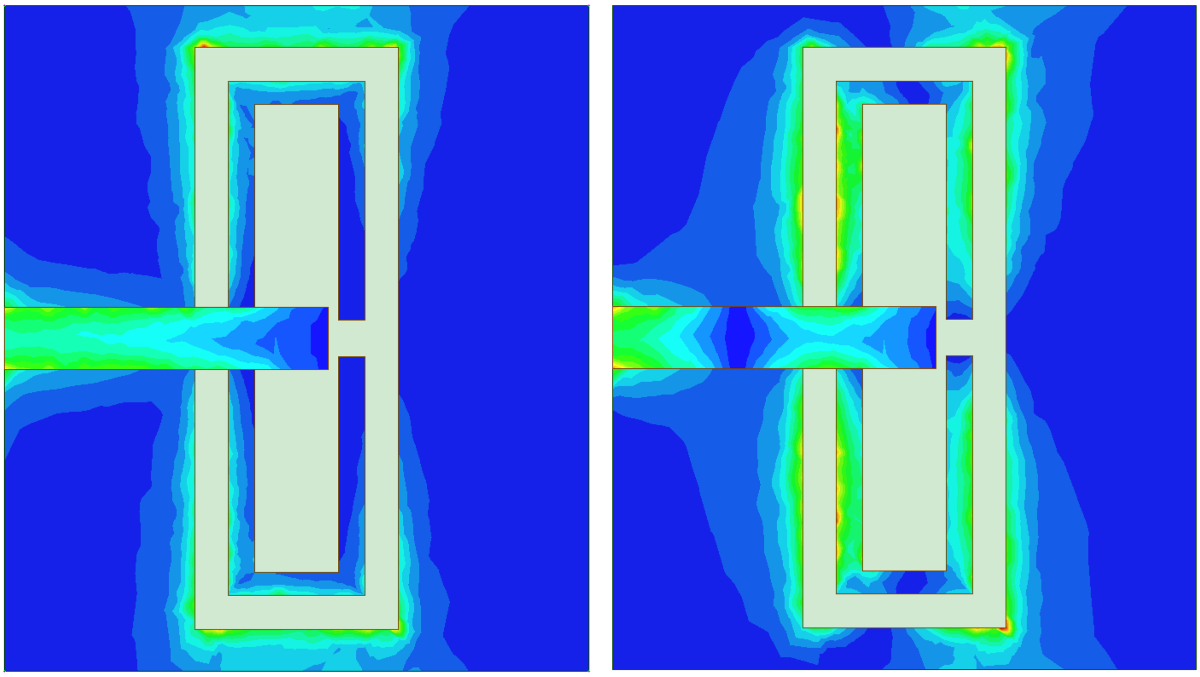
- Stop the optimization once the results are good enough.

1.6 Validation check

In order to get a clearer picture of the quality of the optimized solution the parameter values of the best design need to be pushed into HFSS:

- Find the best design in the Optimization results
- Select that design amoungst the design points: *Right Click on that design point and select 'Copy inputs to Current'*
- *Return to the Project*
- *Right click onto the HFSS setup and select 'Refresh Current Design Point'*
- Open the HFSS Project, adjust the setups to get the fields at 5.8 and 2.4GHz and a sweep from 1.5-7GHz.
- Solve and do the postprocessing as before.


XY Plot 1
HFSSDesign1
Name	X	Y
m1	2.3200	-14.0110
m2	5.9500	-11.5625
Curve Info
dB(St(Feed_T1,Feed_T1))
Setup1 : Sweep
dB(St(Feed_T1,Feed_T1))
Freq [GHz]
XY Plot 1
HFSSDesign1
Name	X	Y
m1	2.4300	-19.3580
m2	5.6900	-21.1131
Freq [GHz]



[1] S. Gai, Y.-C. Jiao, Y.-B. Yang, C.-Y. Li, and J.-G. Gong: ‘DESIGN OF A NOVEL MICROSTRIP-FED DUAL-BAND SLOT ANTENNA FOR WLAN APPLICATIONS‘,*Progress In Electromagnetics Research Letters, Vol. 13, 75-81, 2010*