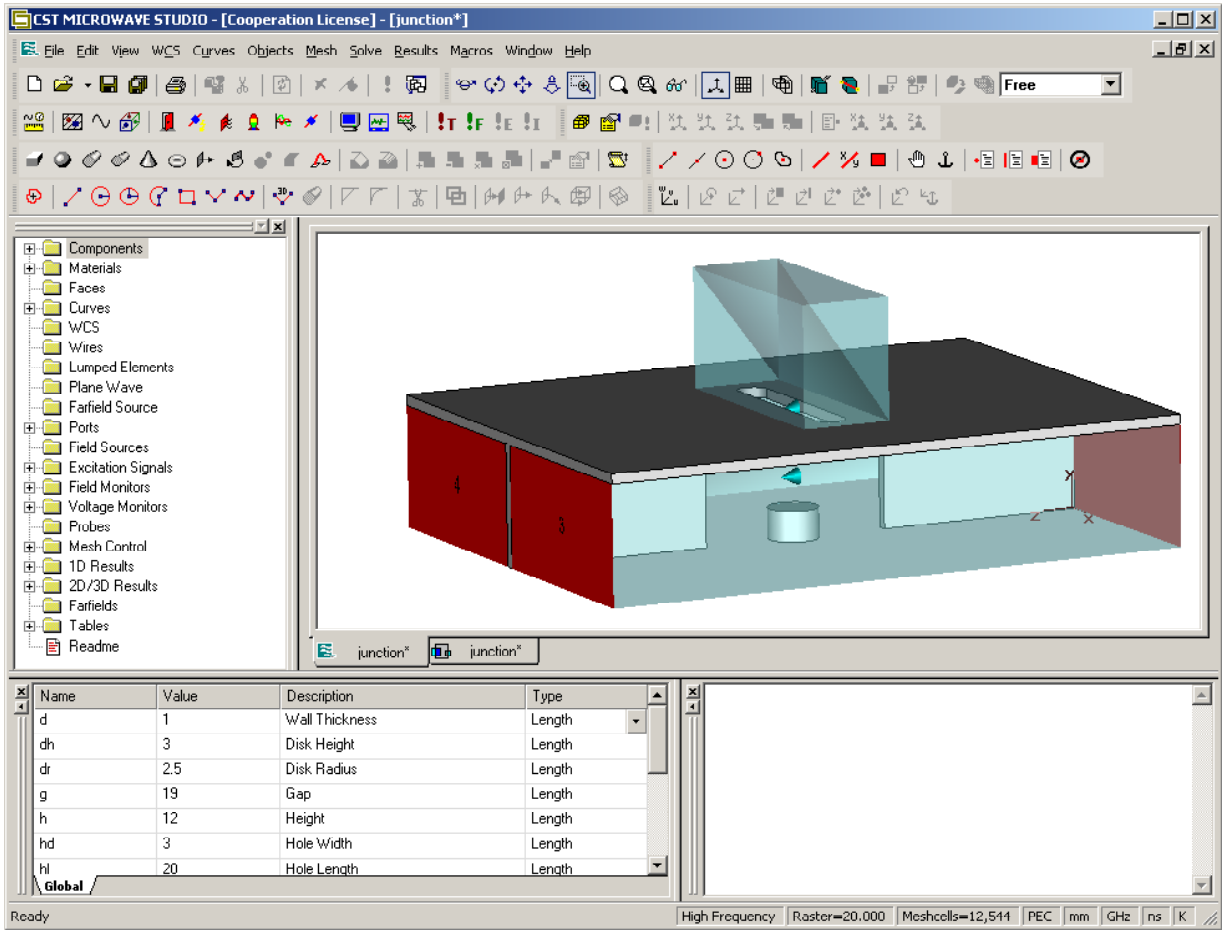
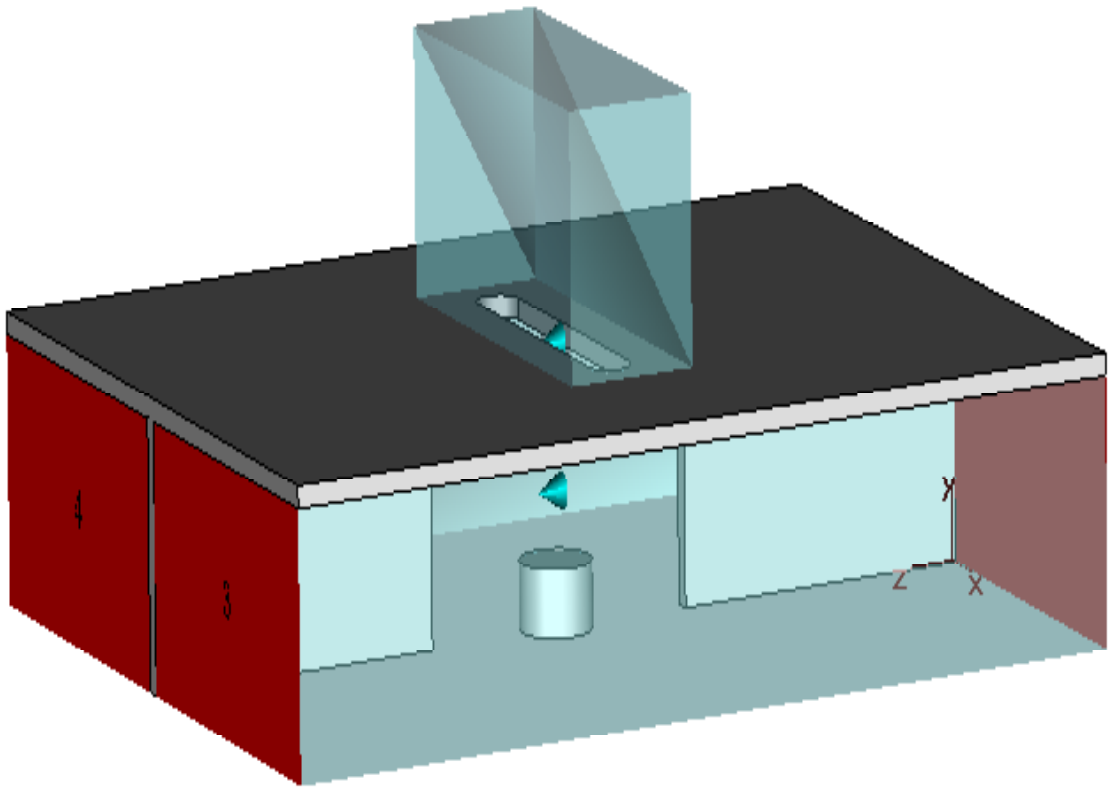
Multi-Objective Optimization and Design Exploration of Waveguide Hybrid Junction in CST Studio Suite



Waveguide Hybrid Junction

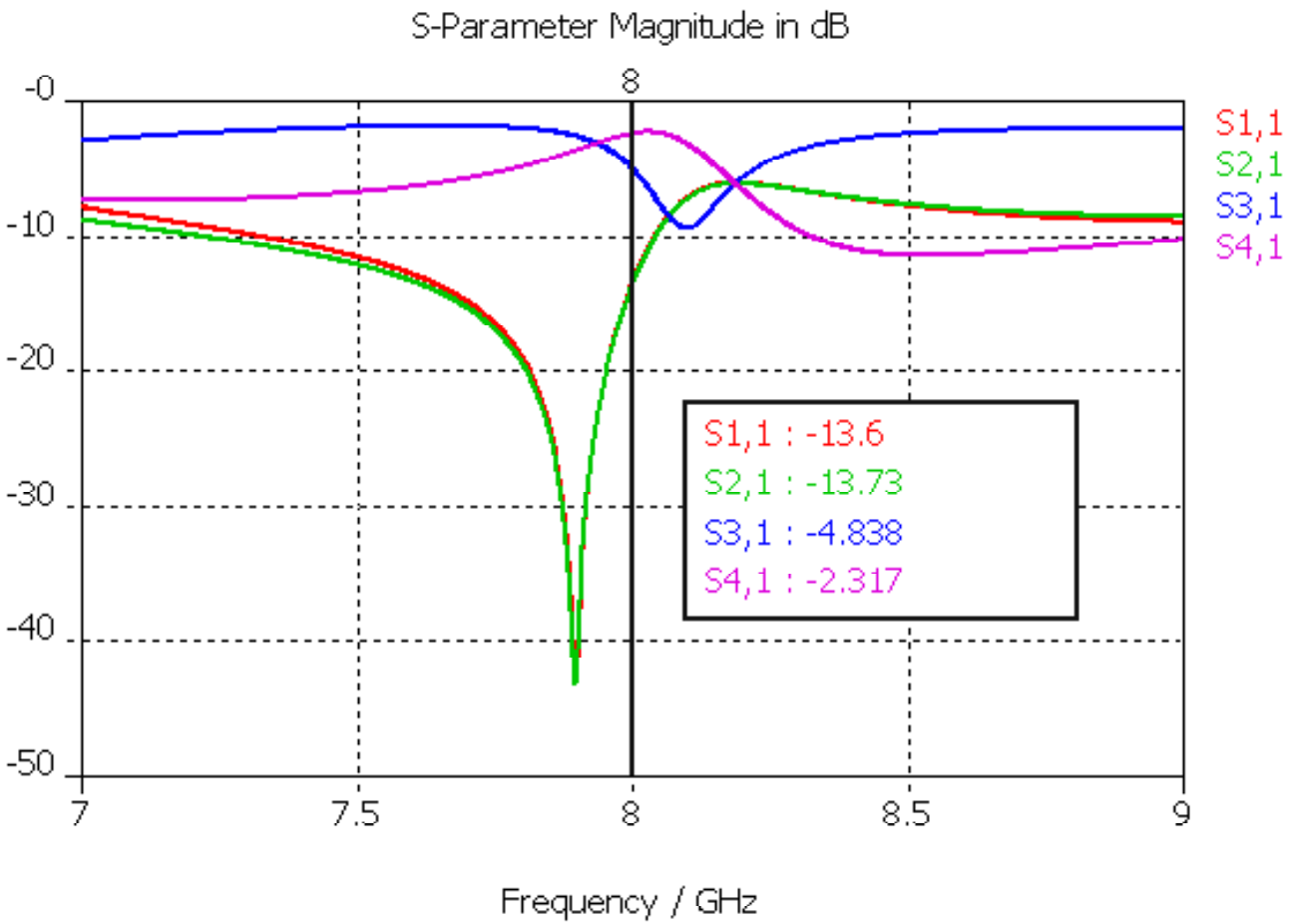


- The S-parameter calculation of a waveguide hybrid junction

- The structure contains a coupling section with a small metallic disk and an external cavity resonator connected to the waveguides by a coupling hole.

- The definition of S-parameter symmetries enables the reduction of performed solver runs.

Simulation of the first Solution

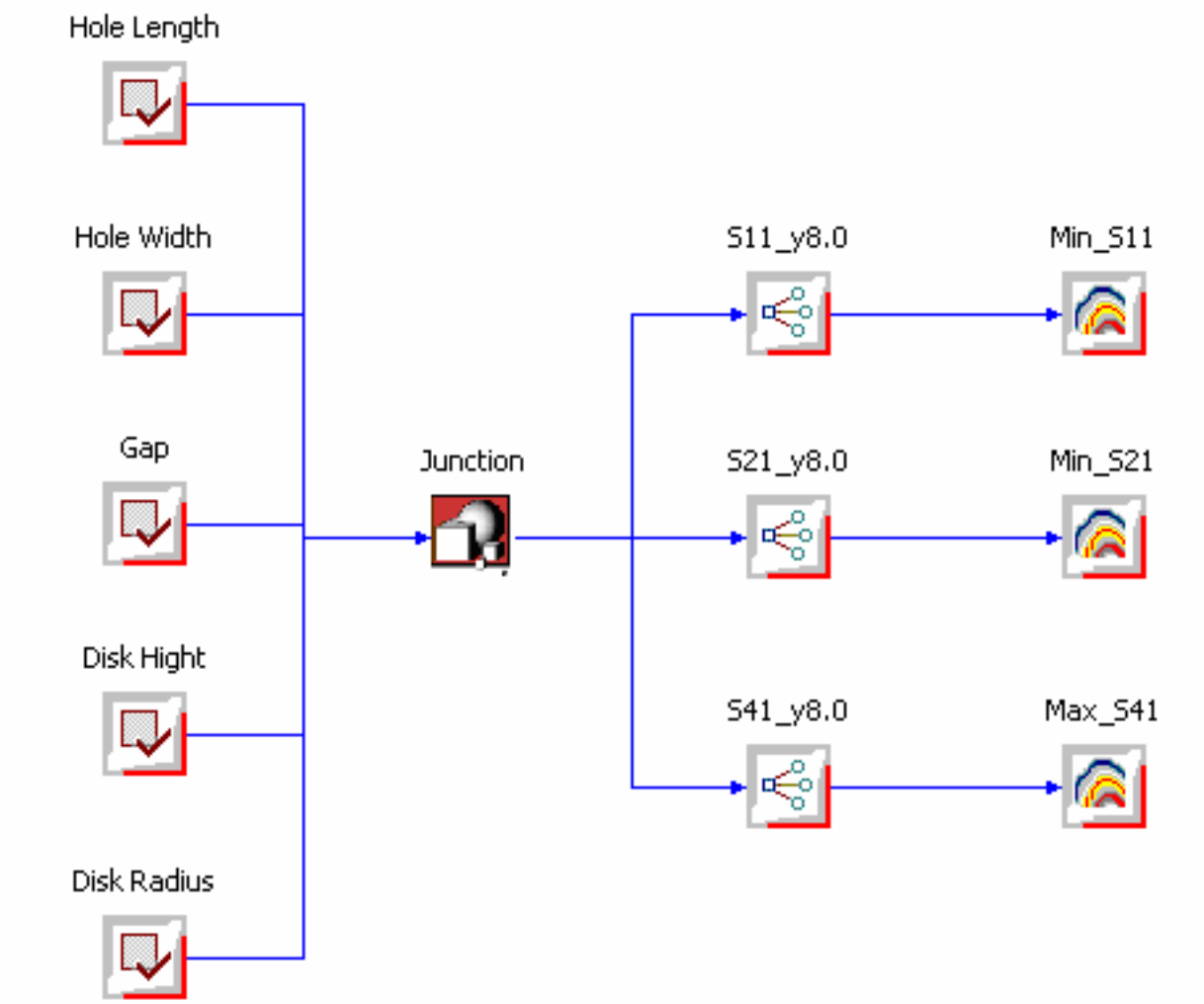


- S-parameter calculation
- The first solution contains the following parameters:

Hole Length = 20
Hole Width = 3
Gap = 19
Disk Hight = 3
Disk Radius = 2.5

- The operating point at 8 GHz is not optimal (bad). The reflection is very high

OptiY Workflow for Optimization



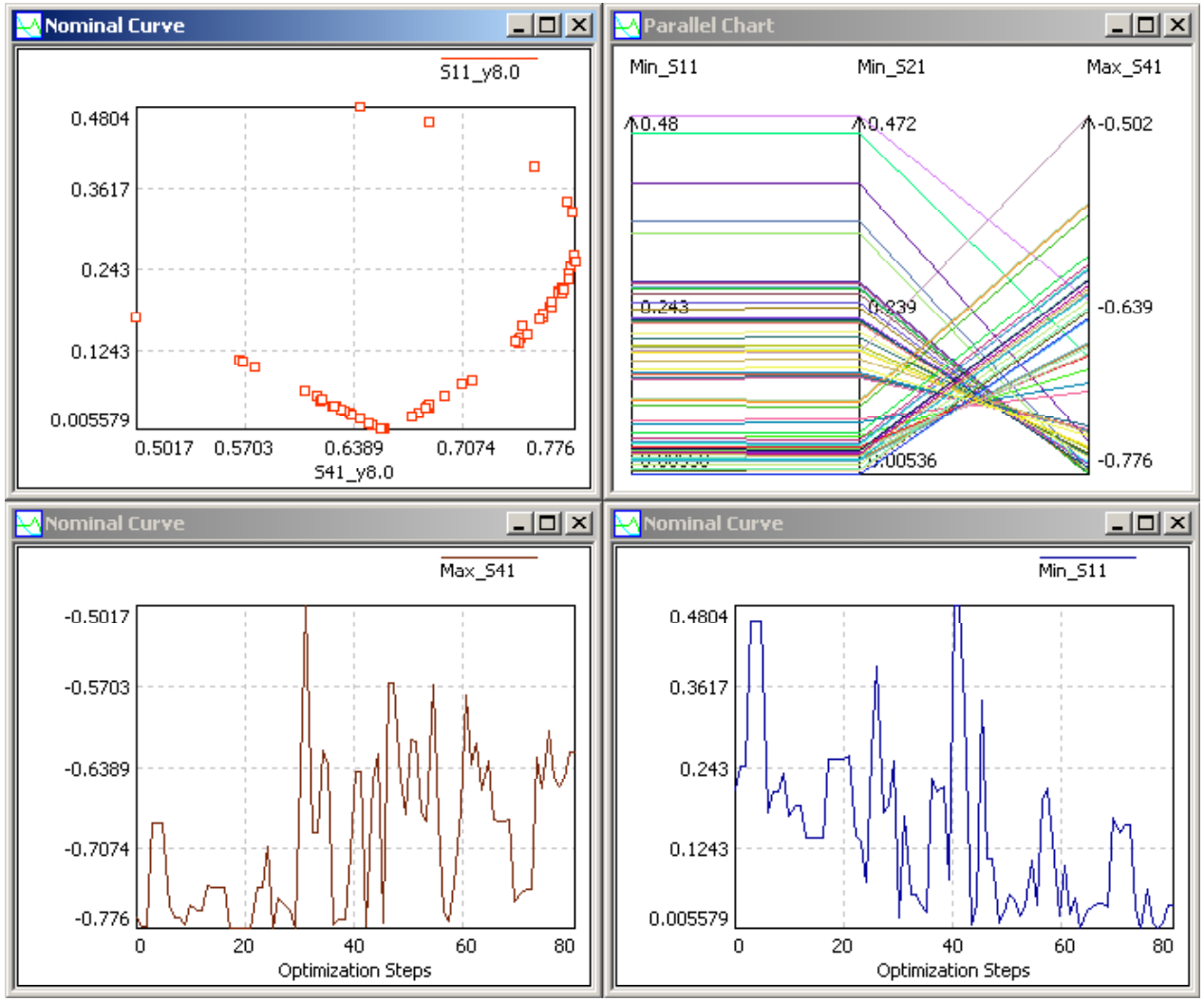
The design parameters:

- 16 ≤ Hole Length ≤ 24
- 2.3 ≤ Hole Width ≤ 3.3
- 27 ≤ Gap ≤ 19
- 3.3 ≤ Disk Hight ≤ 2.8
- 2.8 ≤ Disk Radius ≤ 1.6

The goal is to get the best operating point at 8 GHz:

- minimal Reflections S11, S21
- maximal Transmission S41

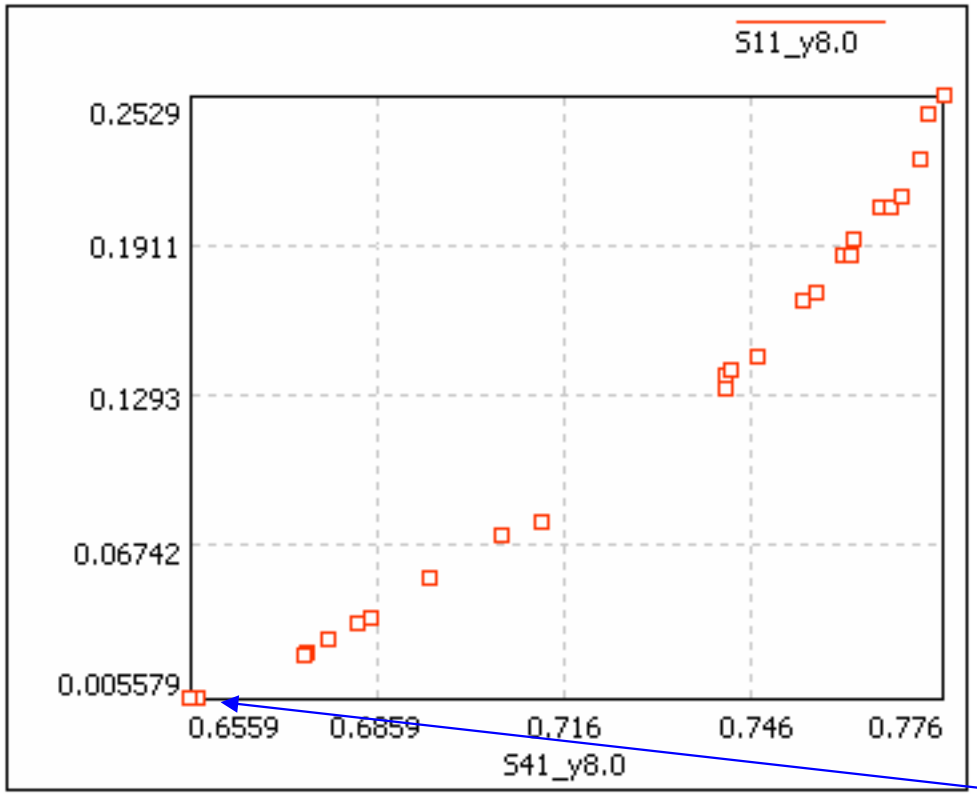
Optimization Process



Optimization options:

- Evolutionary Algorithms
- 80 Optimization steps
- Standard step control

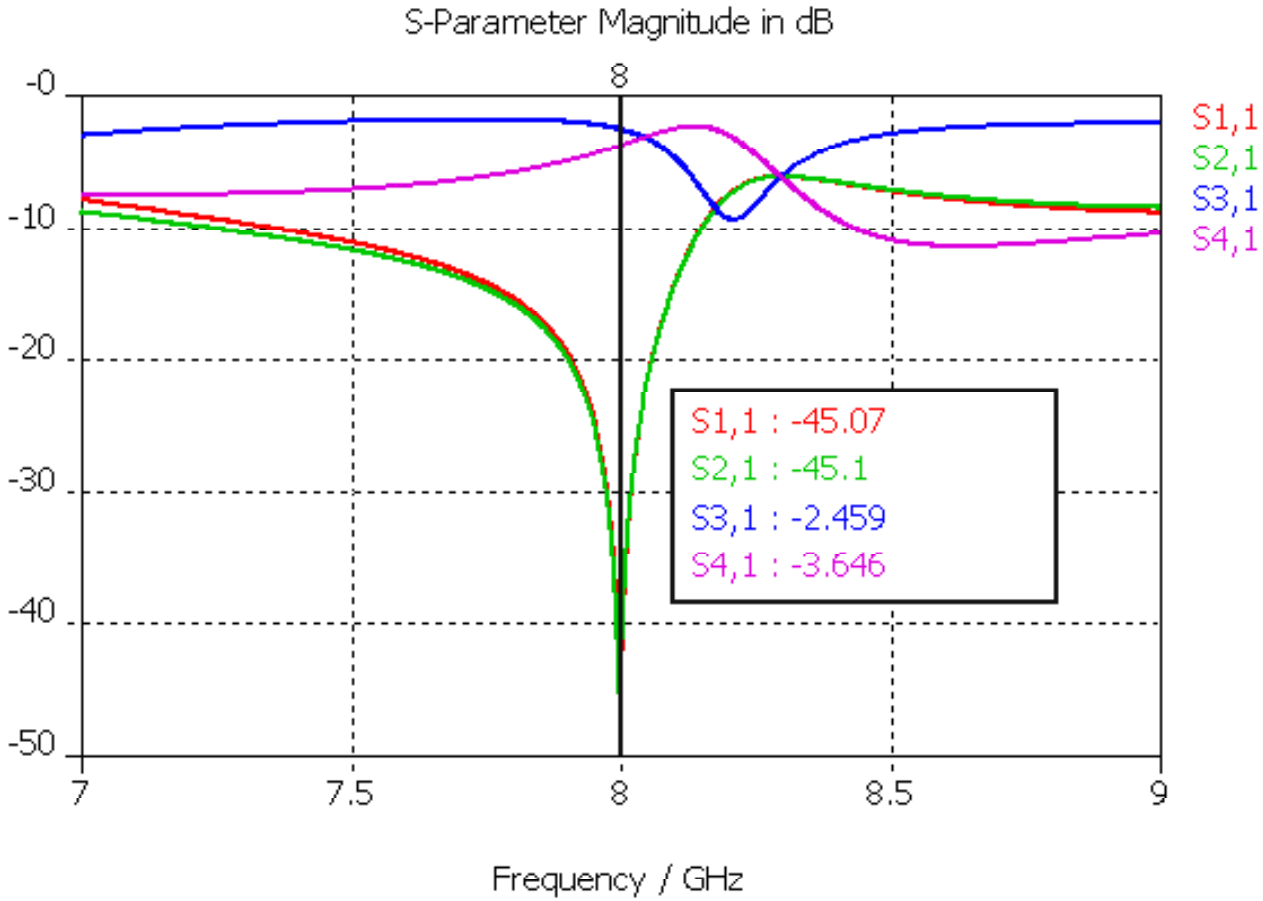
The Pareto-Optimal Solutions



Conflicting goals at the 8 GHz operating point:

- Reflection S11 (Y-axis) verus Transmission S41 (X-axis)
- minimize the reflection leads to minimizing the transmission
- maximize the transmission leads to maximizing the reflection
- The solution at minimal reflection and acceptable transmission is selected as optimal for design exploration

The Ideal Optimal Solution for Design Exploration (Best-Case)

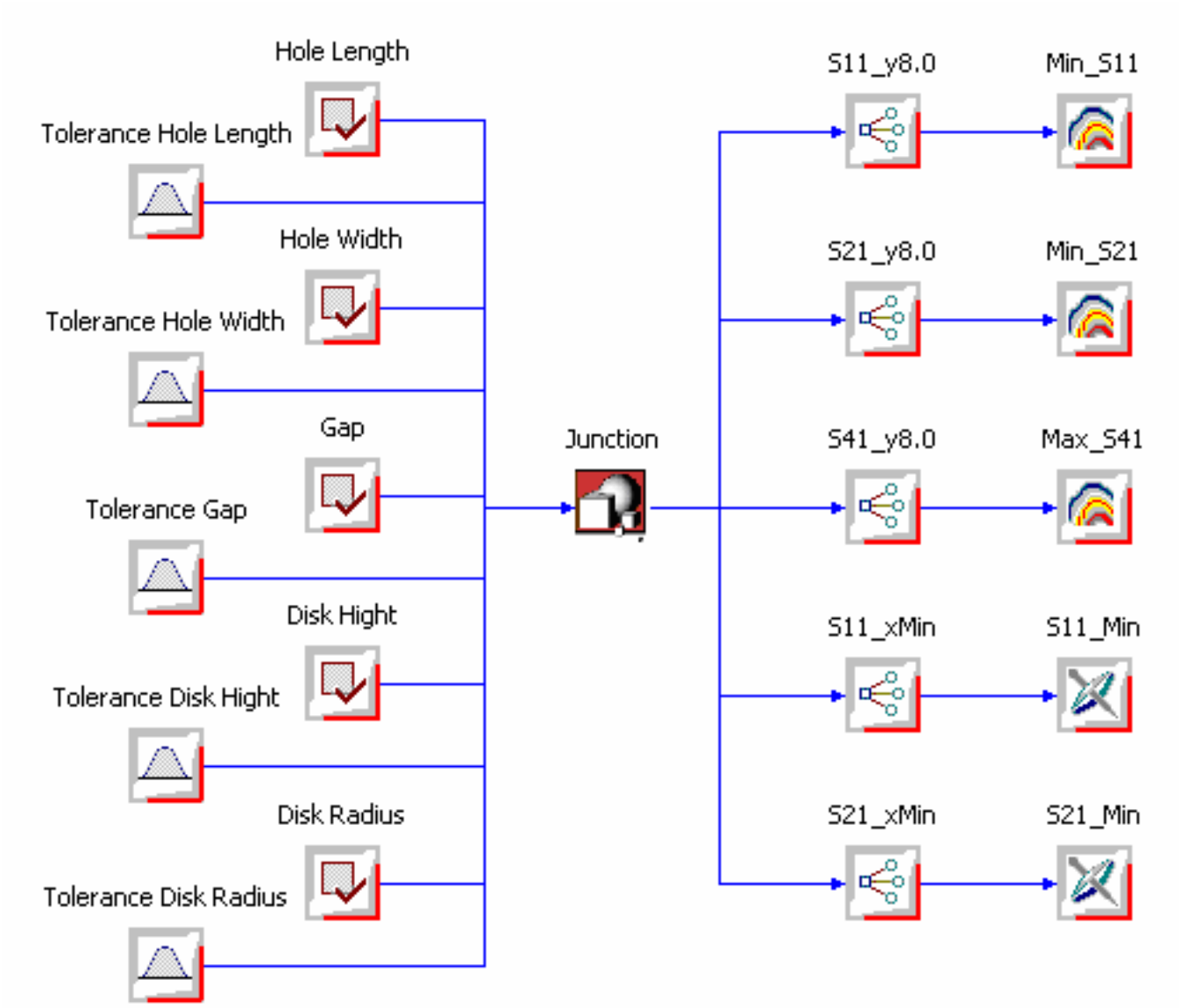


- The solution contains the following parameters:

Hole Length = 19.655
Hole Width = 3.016
Gap = 19.081
Disk Hight = 2.994
Disk Radius = 2.511

- The ideal operating point at 8 GHz is optimal (best case)

OptiY Workflow for Design Exploration



DOE-Method:

- Second Order Moment

All design tolerances :

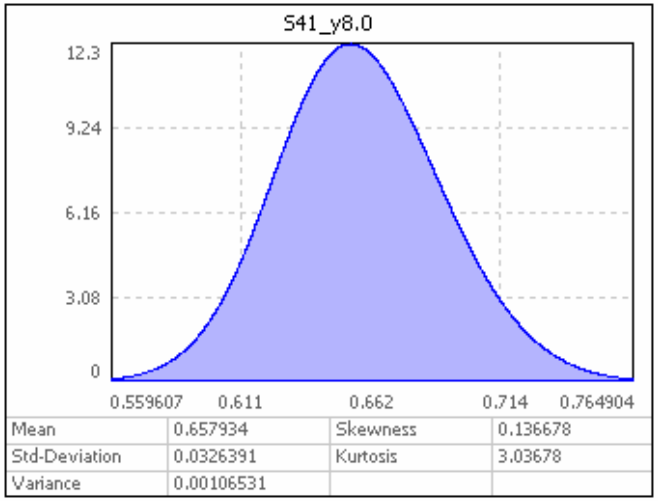
- Tolerance Value = 0.6
- Normal Distribution

The goal is to explore the operating design point at 8 GHz:

- Customer requirement:
e.g. reflection range only
0.1 GHz (7.95 – 8.05 GHz)

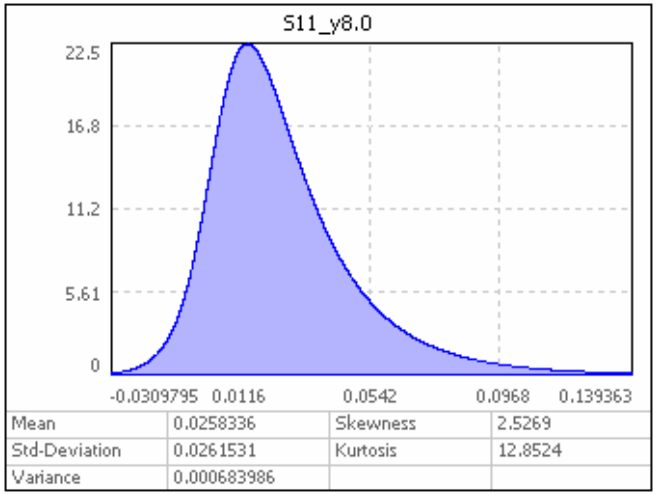
Variations of Reflection and Transmission

- The zero-reflection frequence: 7.9–8.1 GHz (specification: 7.95-8.05 GHz)
- 12.5% of all mass manufactured parts fail the customer requirement
- Worst reflection at operating point 8GHz = 0.13 (linear)
- Worst transmission at operating point 8GHz = 0.55 (linear)



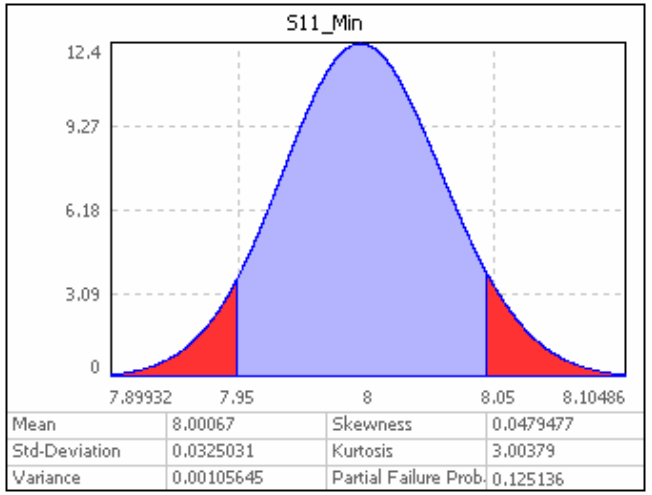
Mean	0.657934	Skewness	0.136678
Std-Deviation	0.0326391	Kurtosis	3.03678
Variance	0.00106531		

Transmission at 8 GHz
0.55 – 0.76



Mean	0.0258336	Skewness	2.5269
Std-Deviation	0.0261531	Kurtosis	12.8524
Variance	0.000683986		

Reflection at 8 GHz
0 – 0.13

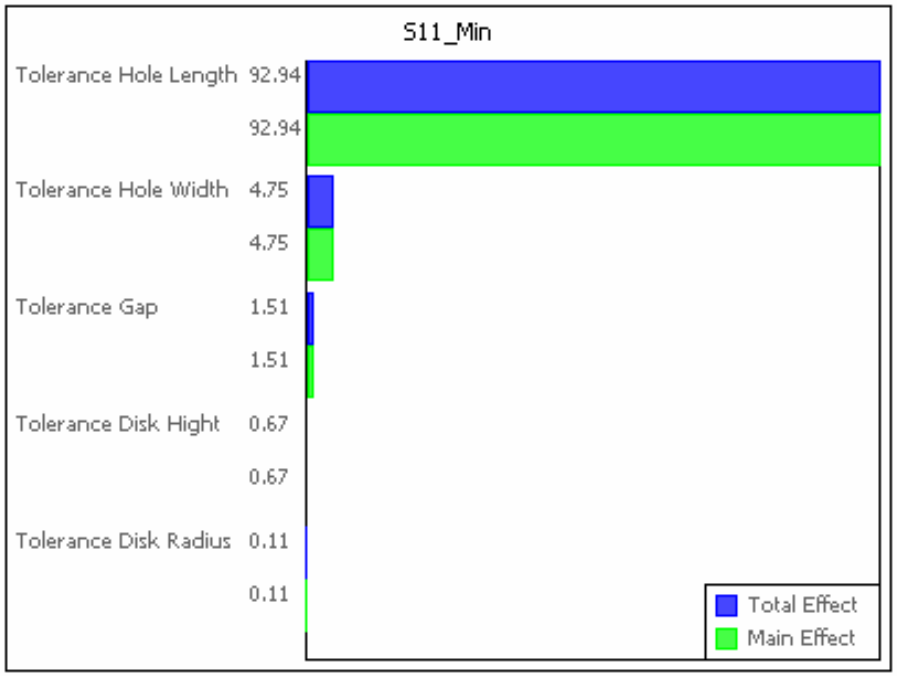


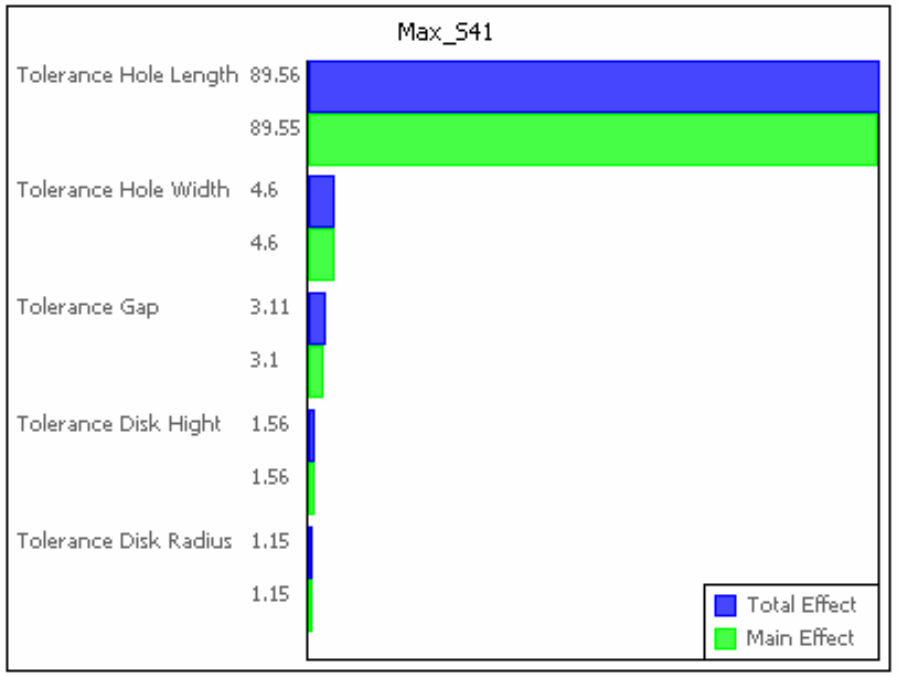
Mean	8.00067	Skewness	0.0479477
Std-Deviation	0.0325031	Kurtosis	3.00379
Variance	0.00105645	Partial Failure Prob.	0.125136

Zero-Reflection Frequence
7.9 – 8.1 GHz

Global Sensitivity Analysis

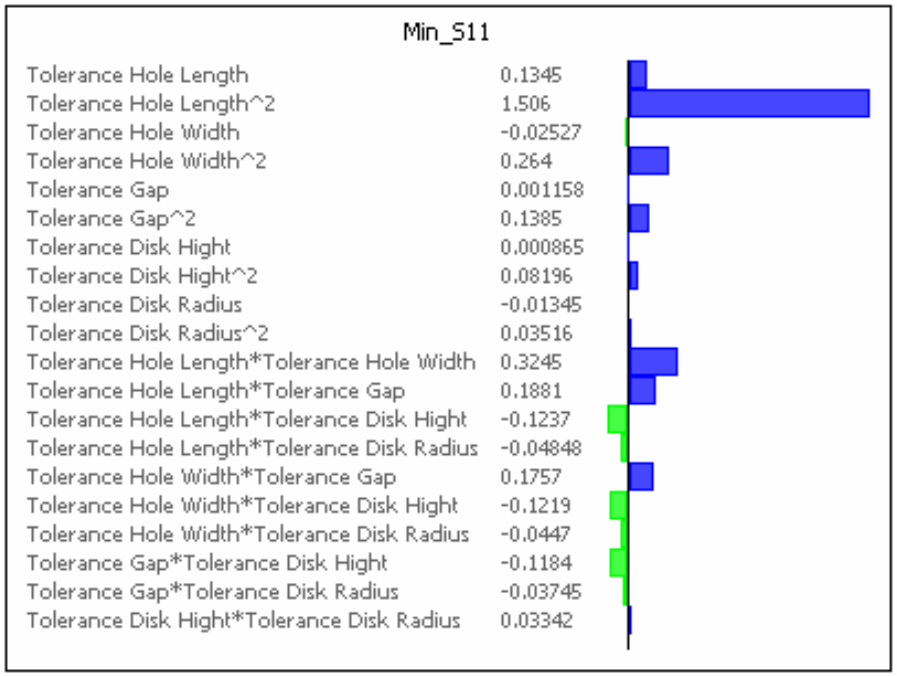
- The Hole geometry tolerances (Length and Width) contribute the most to the variablity of reflection and transmission. Its should be minimized to reduce the output variability
- The Disk geometry and the Gap are insignificant and can be eleminated from the model
- There are no interactions between inputs (main effect = total effect)

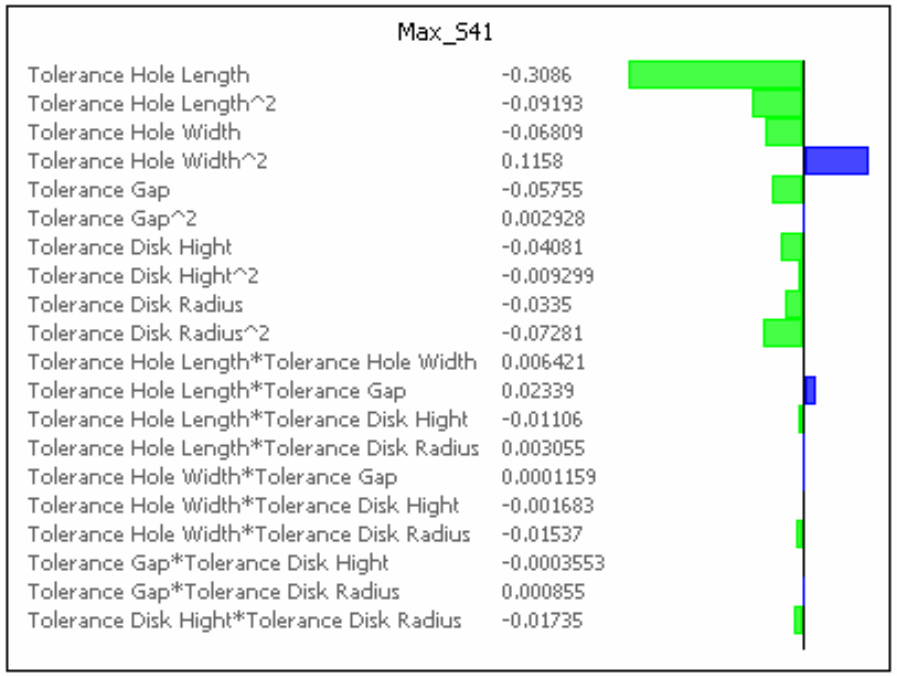




Local Sensitivity Analysis

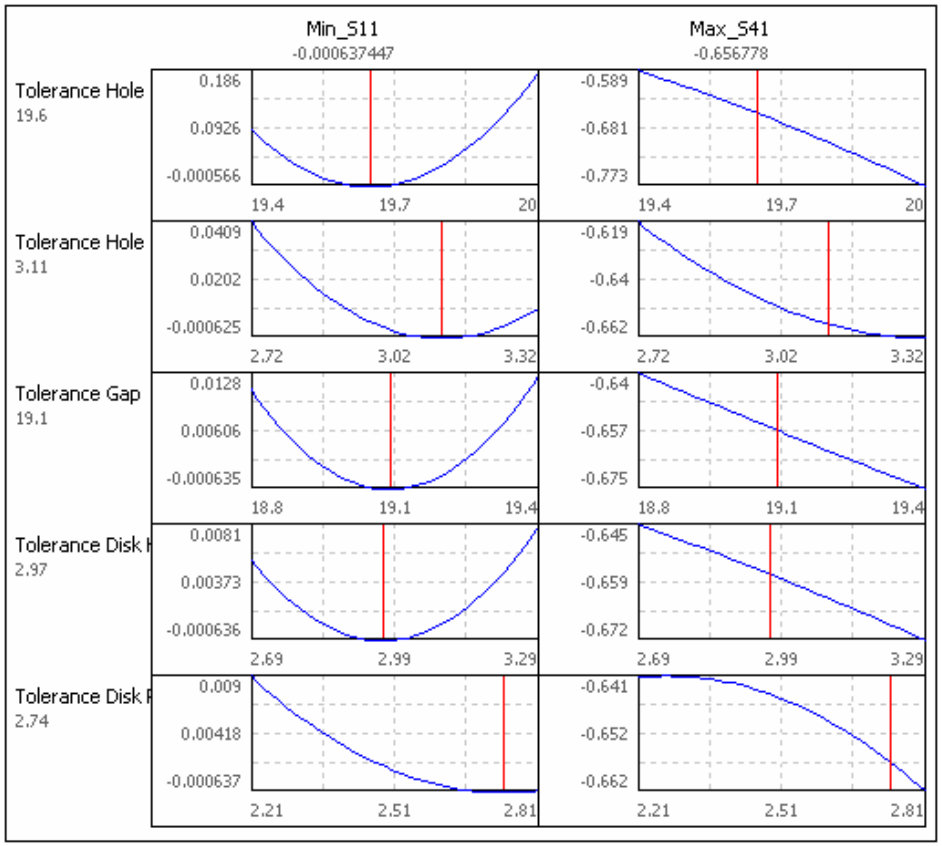
- The coefficients of the Taylor-series are shown
- The value change of the Hole geometry (nominal values) cause the most value change of the transmission and the reflection (nominal values)
- There ar quadratic and interactive correlations between inputs

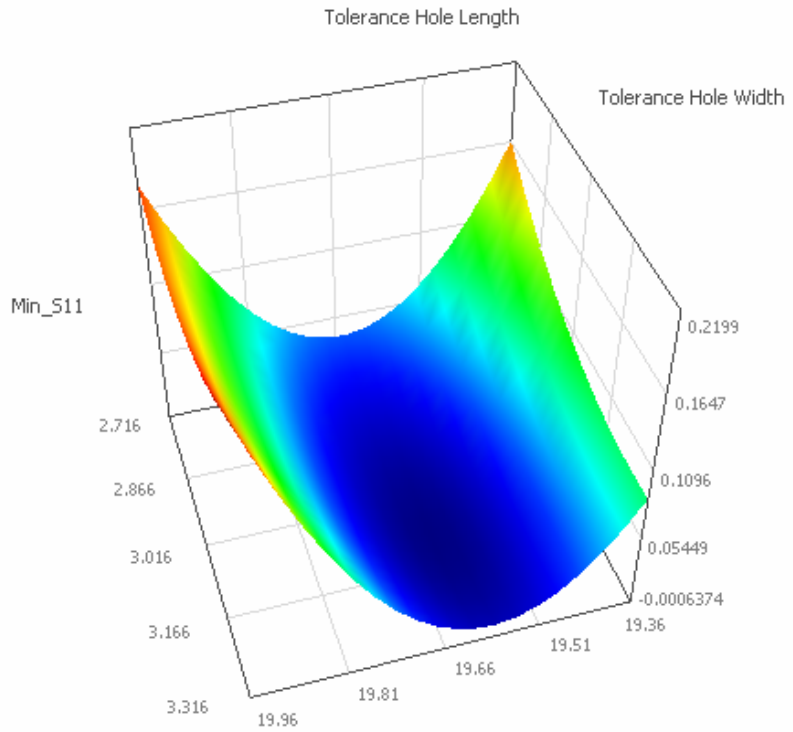




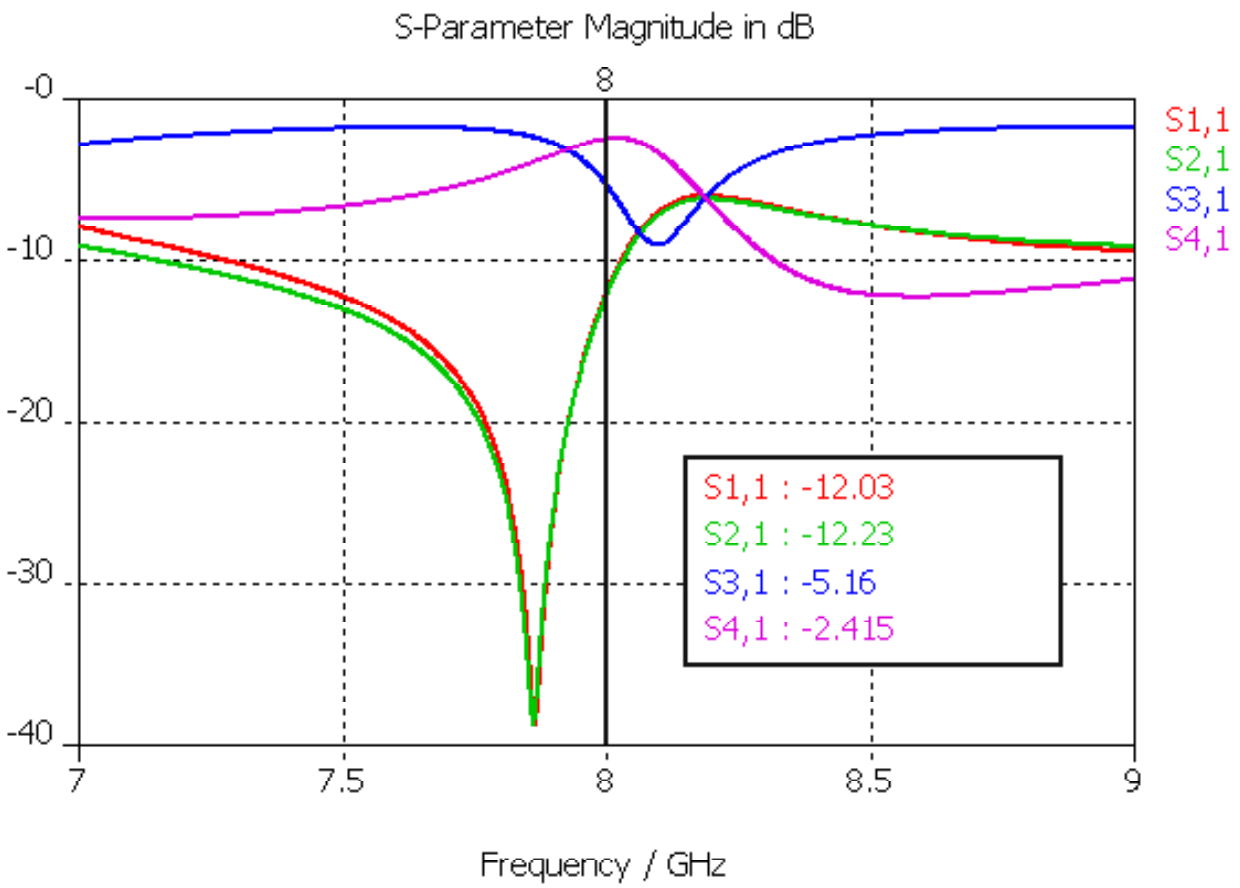
Response Surface

- Graphical 2D and 3D Diagrams of the Taylor-series are shown
- Approximation to the surrogate model
- Optimization with the surrogate model
- Best- and Worse-Case Simulation





The Worse-Case Simulation



The worse case solution within the tolerance space at the operating design point 8GHz:

Reflection: -12 dB
Transmission: -2.4 dB

At the design parameter combination:

Hole Length = 19.952
Hole Width = 3.316
Gap = 19.378
Disk Hight = 2.698
Disk Radius = 2.211