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A Novel Antenna Optimization Approach Using optiSLang and HFSS Analytical Derivatives

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17th Weimar Optimization and Stochastic Days 2020

June 25 – 26, 2020

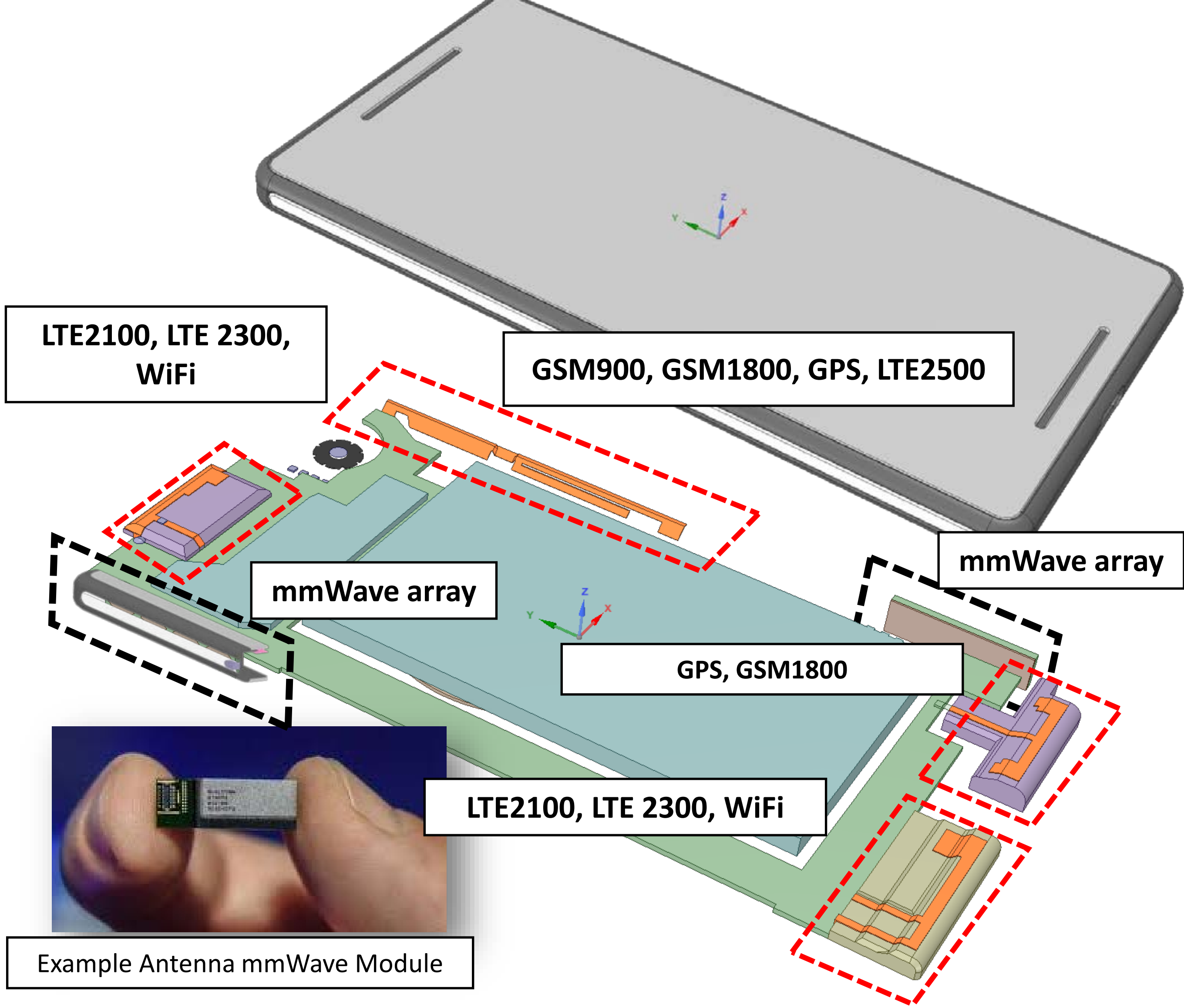
Virtual Conference

Agenda

- Motivation for antenna optimization
- What is Ansys HFSS?
- Antenna optimization workflow:
  - HFSS calculates partial derivatives to create a metamodel of the antenna response
  - optiSLang optimizes metamodel and iterates the optimization process
- Optimization example: antenna with nine input parameters
- Summary

Why optimize antennas?

- Antennas are everywhere!
  - Wireless communication, IoT, any "smart" device, etc.
- Individual devices commonly use several antennas that have to operate without interfering with each other
- Cell phone example:
  - 3G/4G antennas: Single element and multi-band
  - Additional services: WiFi, BT, GPS…
  - 5G antennas: Multiple phased arrays

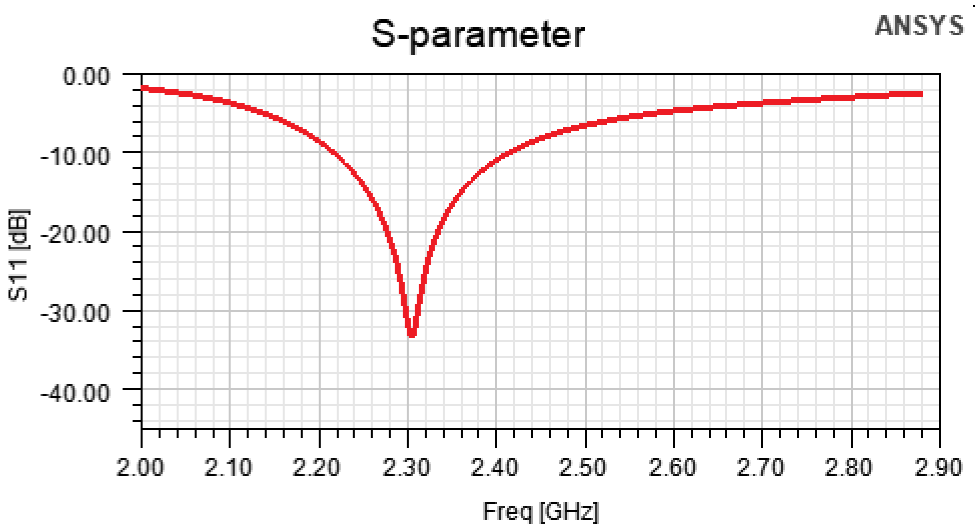


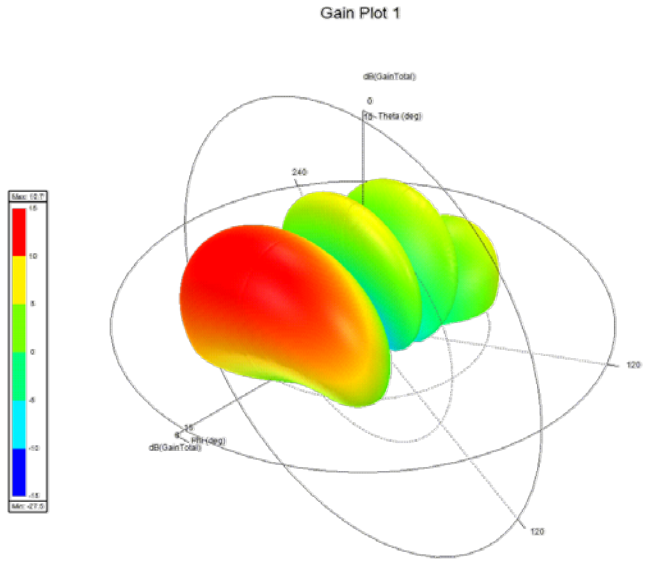
Example Antenna mmWave Module

- An optimized antenna is important for efficient device performance: Improved communication range, battery life, etc.

Ansys HFSS: 3D high frequency electromagnetic solver

- HFSS for antenna simulations
  - Common outputs: S-parameters, antenna impedance, radiation patterns, etc.



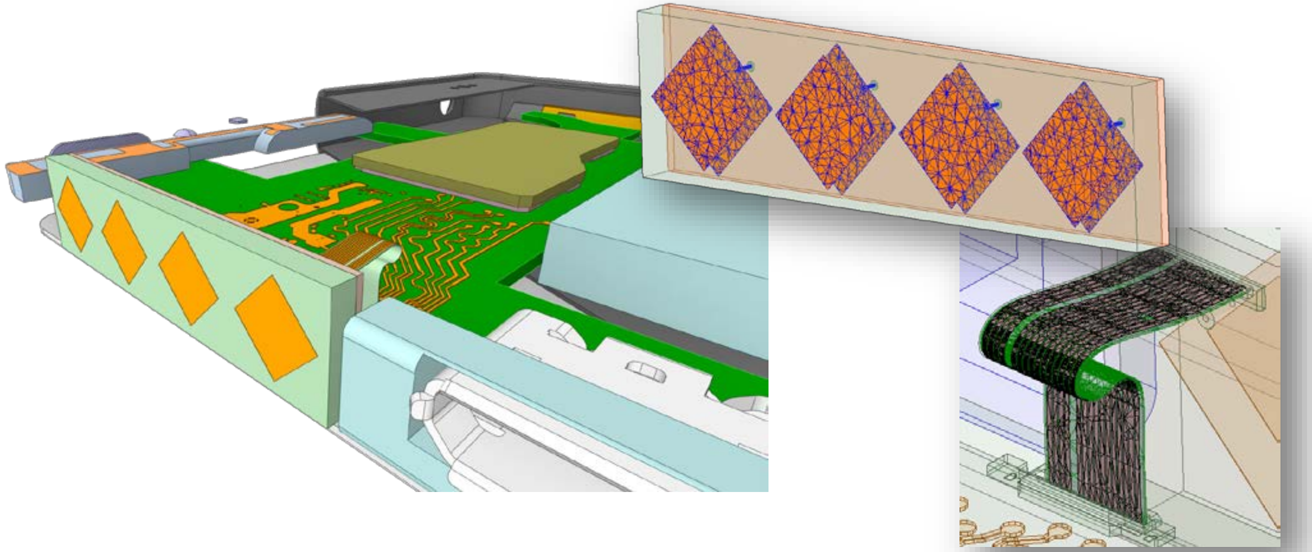


- HFSS can calculate partial derivatives of antenna response to optimization parameters:
  - Geometry dimensions and material property values

Automated accuracy with HFSS

- Reliable solutions depend on accurate meshing
  - Geometry defines the mesh, mesh is solved
  - Tetrahedral mesh is conformal to geometry

- Automatic adaptive meshing
  - Automatic mesh creation
  - Automatic mesh refinement
  - Accurate and efficient solution

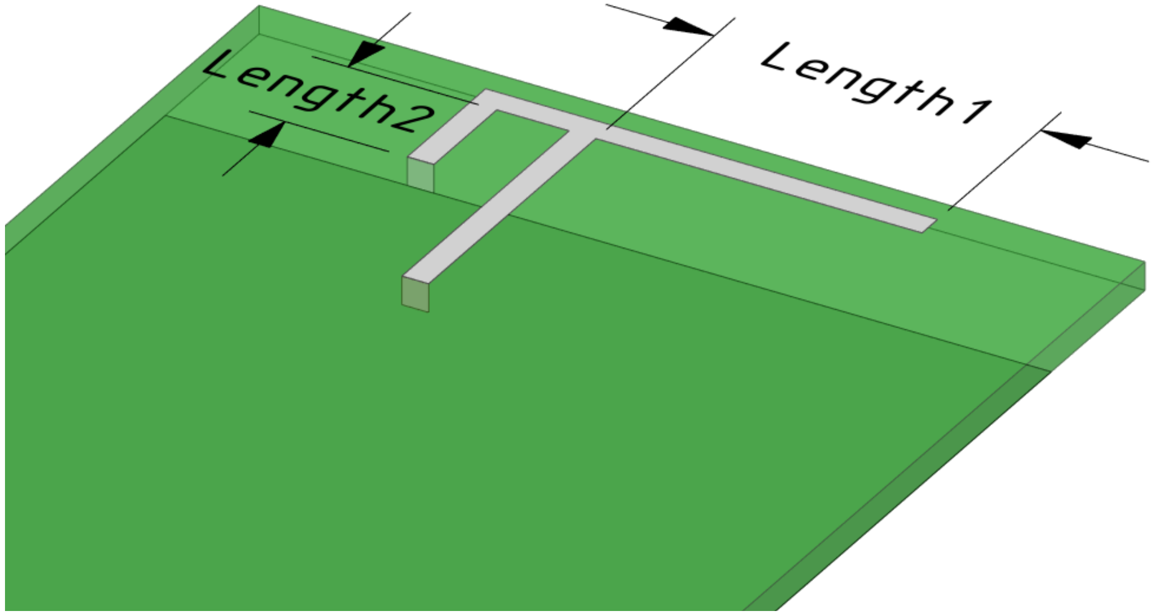


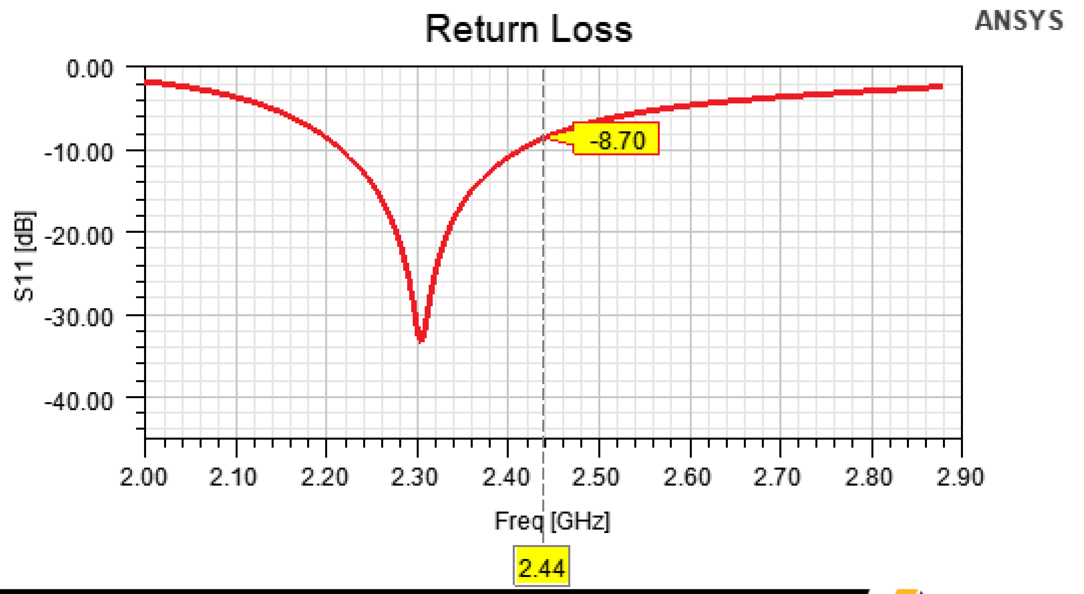
Optimization workflow: PIFA

- Planar inverted-F antennas (PIFA) are commonly used in printed circuit board applications

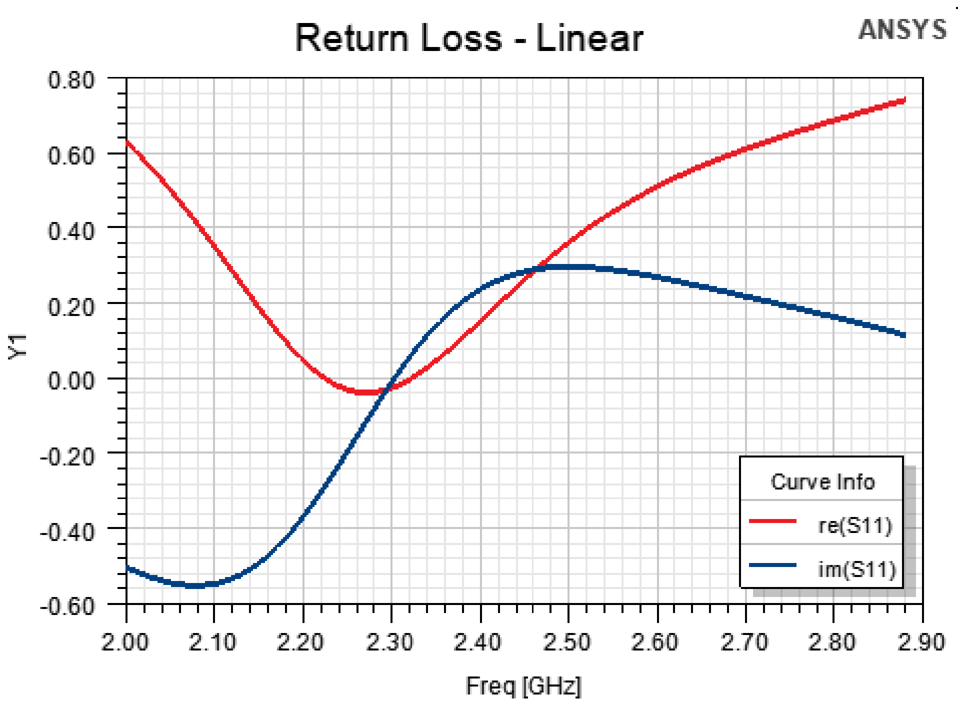
- HFSS was used to calculated the antenna’s S-parameters
  - The dip in S11 indicates that this antenna resonates at 2.3 GHz

- Optimization goal:
  Modify Length1 and Length2 so that antenna resonates at 2.44 GHz

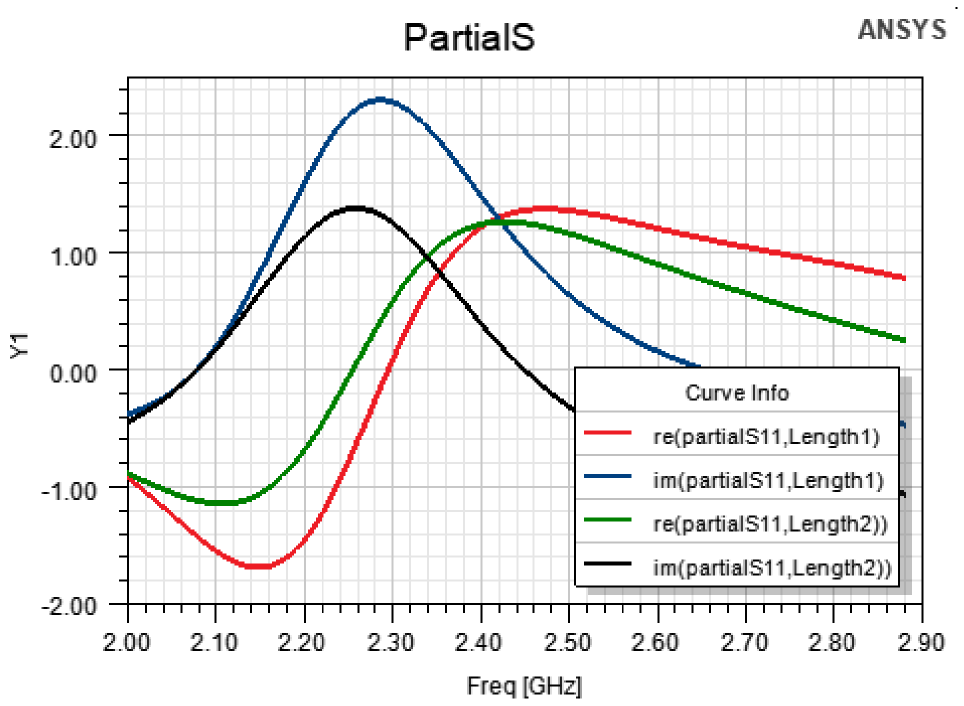




HFSS output



Real and imaginary parts of S11



Real and imaginary parts of partial derivatives with respect to the optimization parameters: Length1 and Length2

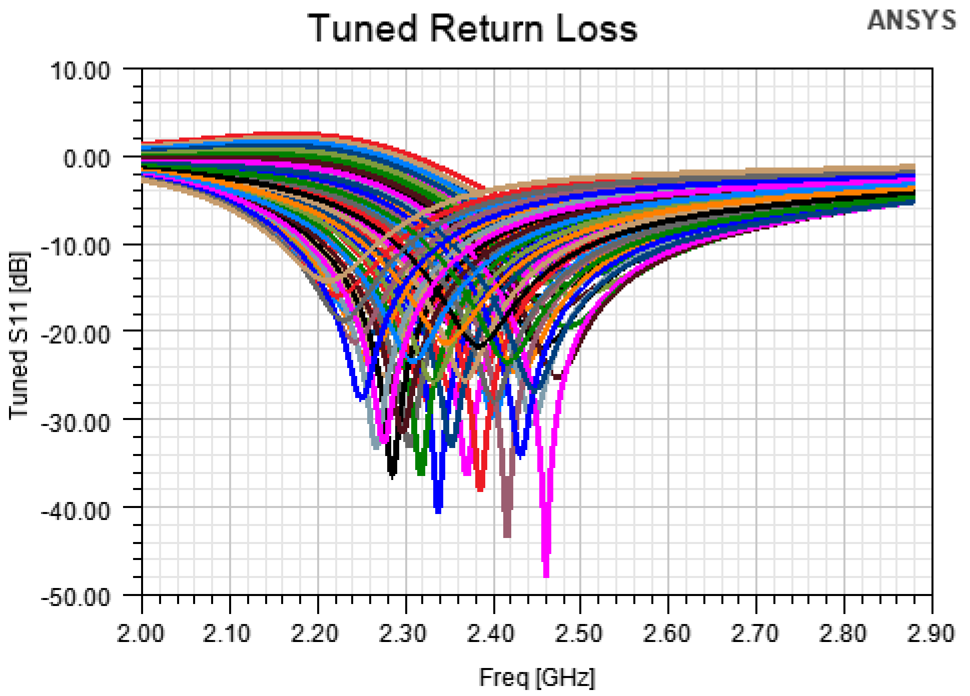
Derivative based metamodel

- Using partial derivatives, S-parameters can be predicted for tuned optimization parameter values:

$$S11_{tuned} = S11_{nominal} + \Delta S11_{Length1} + \Delta S11_{Length2}$$

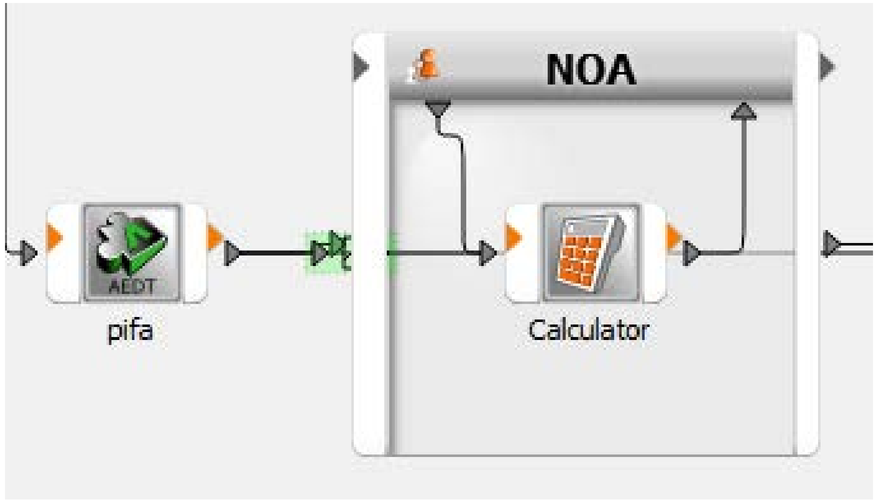
$$\Delta S11_{Length1} = \frac{\delta S11}{\delta Length1}(Length1_{tuned} - Length1_{nominal})$$

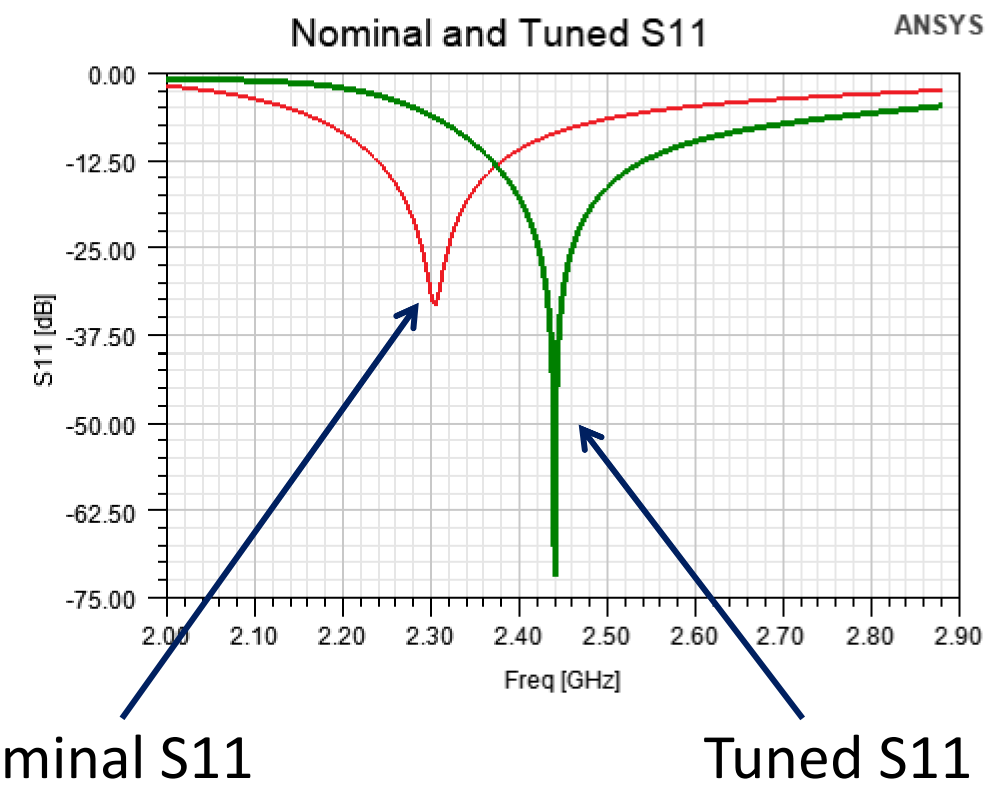
$$\Delta S11_{Length2} = \frac{\delta S11}{\delta Length2}(Length2_{tuned} - Length2_{nominal})$$



How to find the best tuned design?

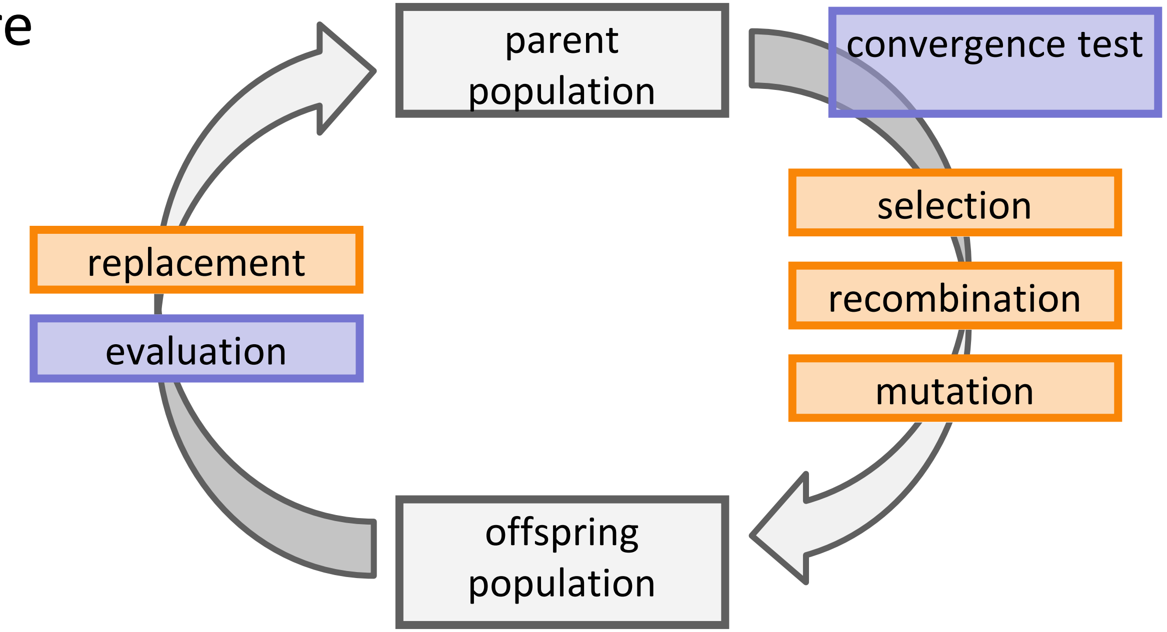
- Metamodel optimization using NOA (nature-inspired optimization algorithm) in optiSLang
  → Minimize return loss at desired frequency





optiSLang's nature-inspired optimization algorithm offerings

- Evolutionary Algorithm (EA) from the group of Nature-inspired Optimization Algorithms (NOA)
- Imitates Evolution ("Optimization") in Nature
  - Survival of the fittest
  - Evolution due to mutation, recombination and selection
  - Developed for optimization problems where no gradient information is available
- Strength:
  - Optimization tasks with multiple local minima
  - Discovering of new design variations
- Weakness:
  - Many designs to converge on optimum → no problem for metamodel optimization approach!



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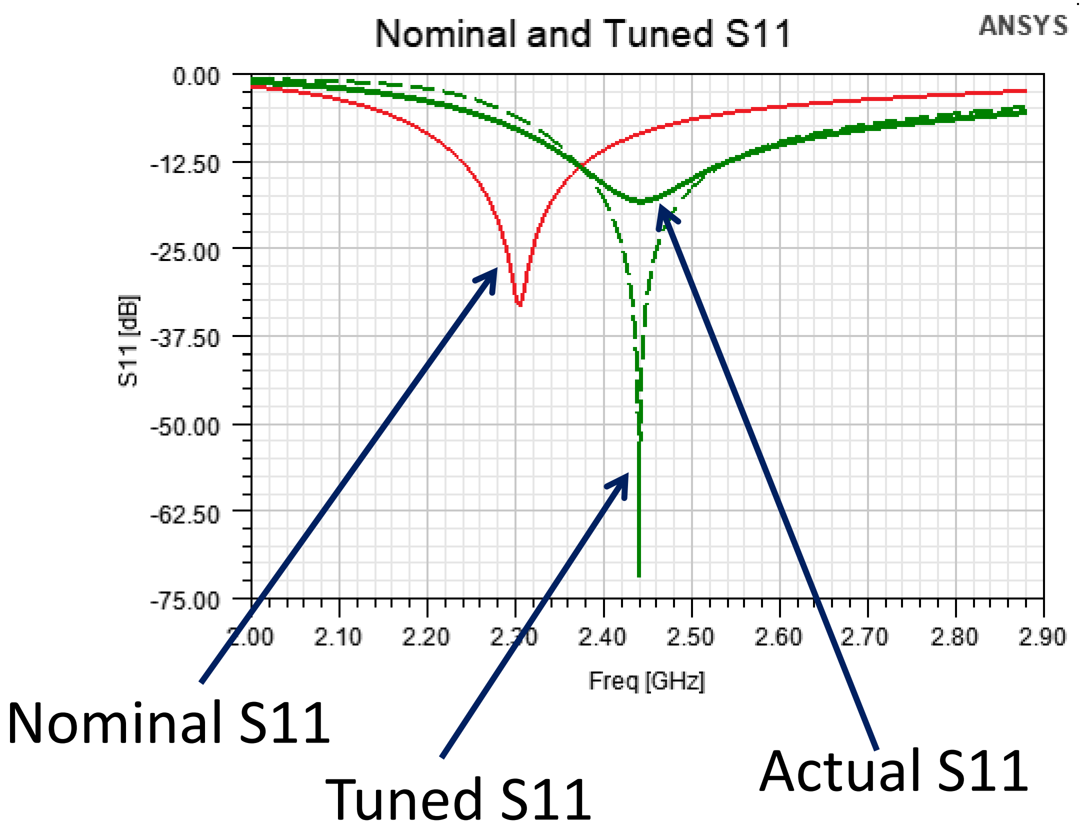
Complication in optimization approach

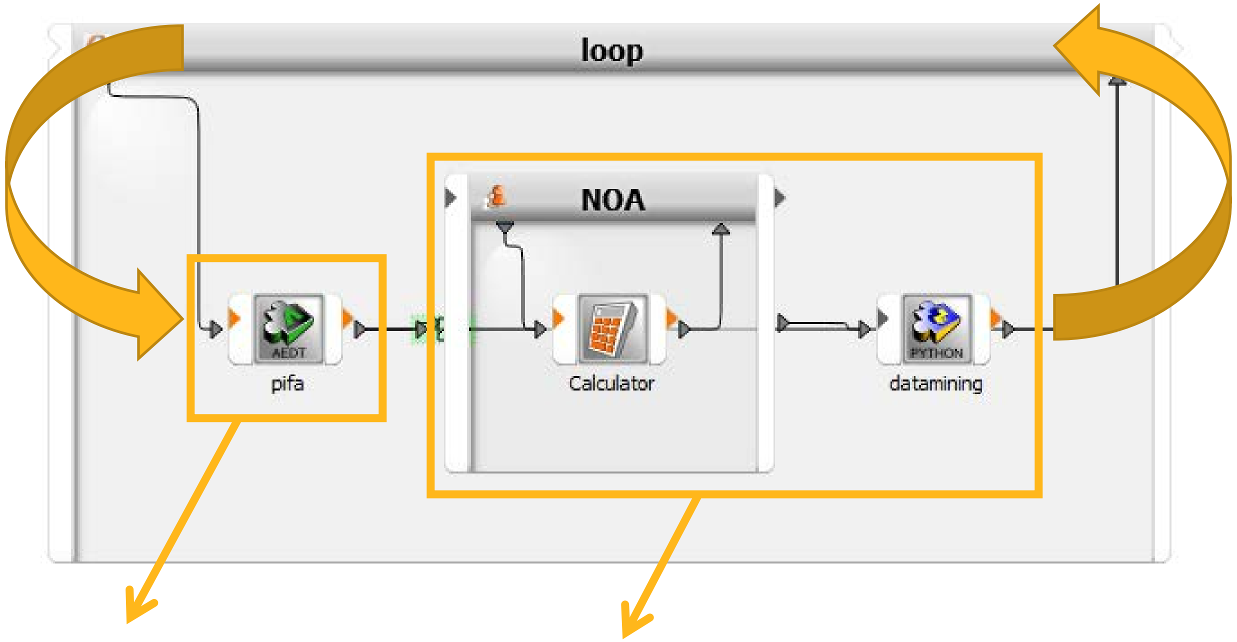
- Partial derivatives predict a linear change in antenna response
- However, the antenna response varies non-linearly with changes in the optimization parameters
  - The larger the change in the optimization parameters, the larger the inaccuracy in antenna response prediction



- Solution: iterative approach

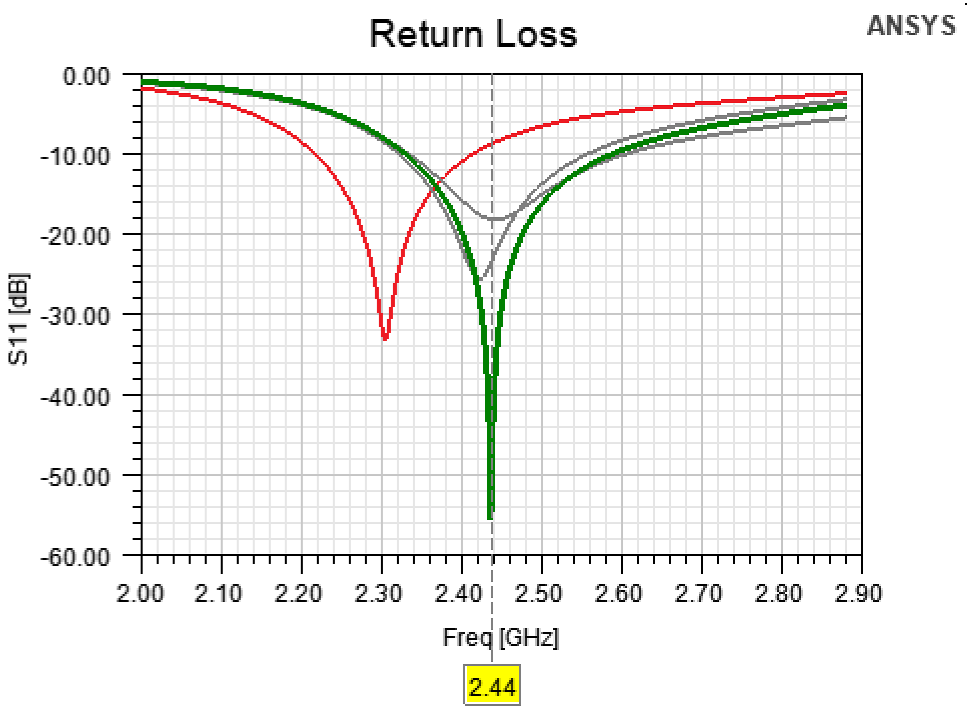
Automation with optiSLang

Loop:
Update HFSS parameters and repeat HFSS and NOA execution



AEDT-node:
HFSS evaluates design and provides derivatives

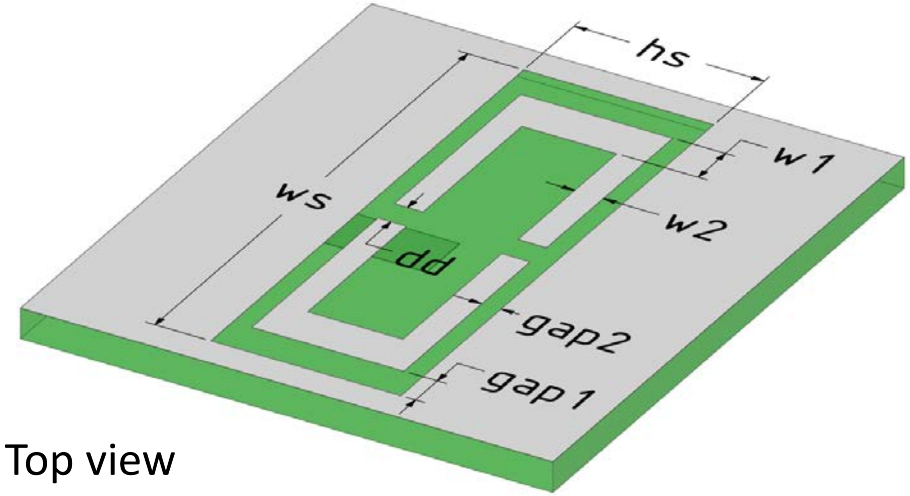
NOA:
Optimizes derivative based metamodel to determine best tuned design



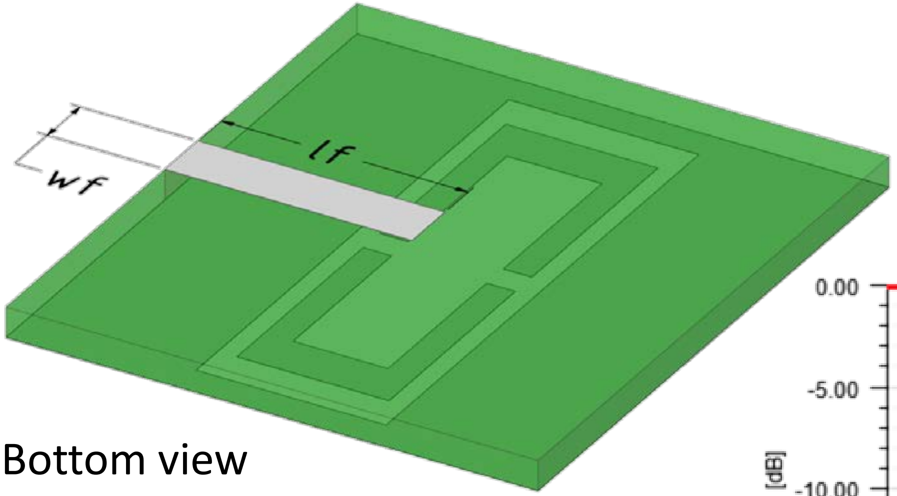
A great design is determined in four iterations:
At frequency of interest: S11 is better than -40 dB!

Optimization example: dual-band antenna

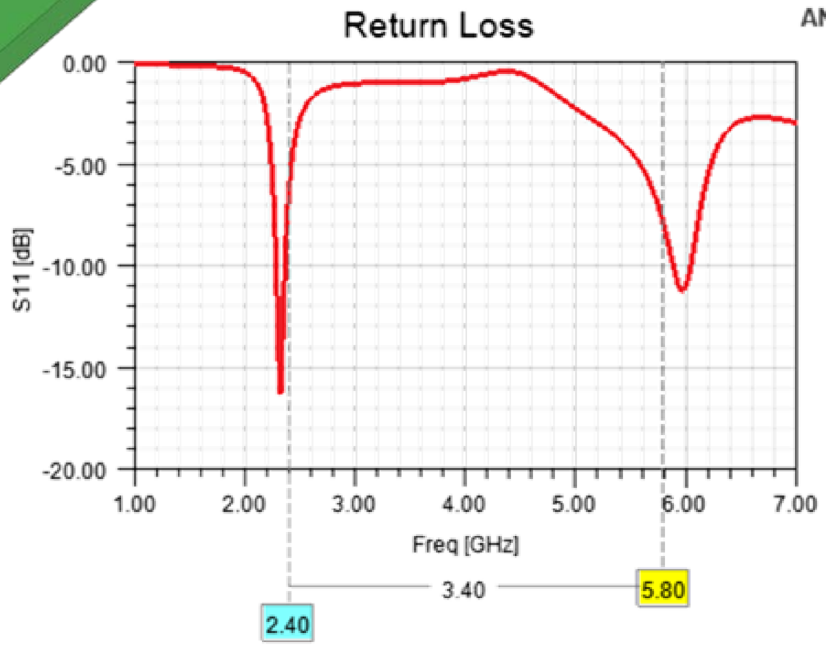
- Microstip coupled slot antenna [1] is intended to resonate in two wifi bands



Top view



Bottom view

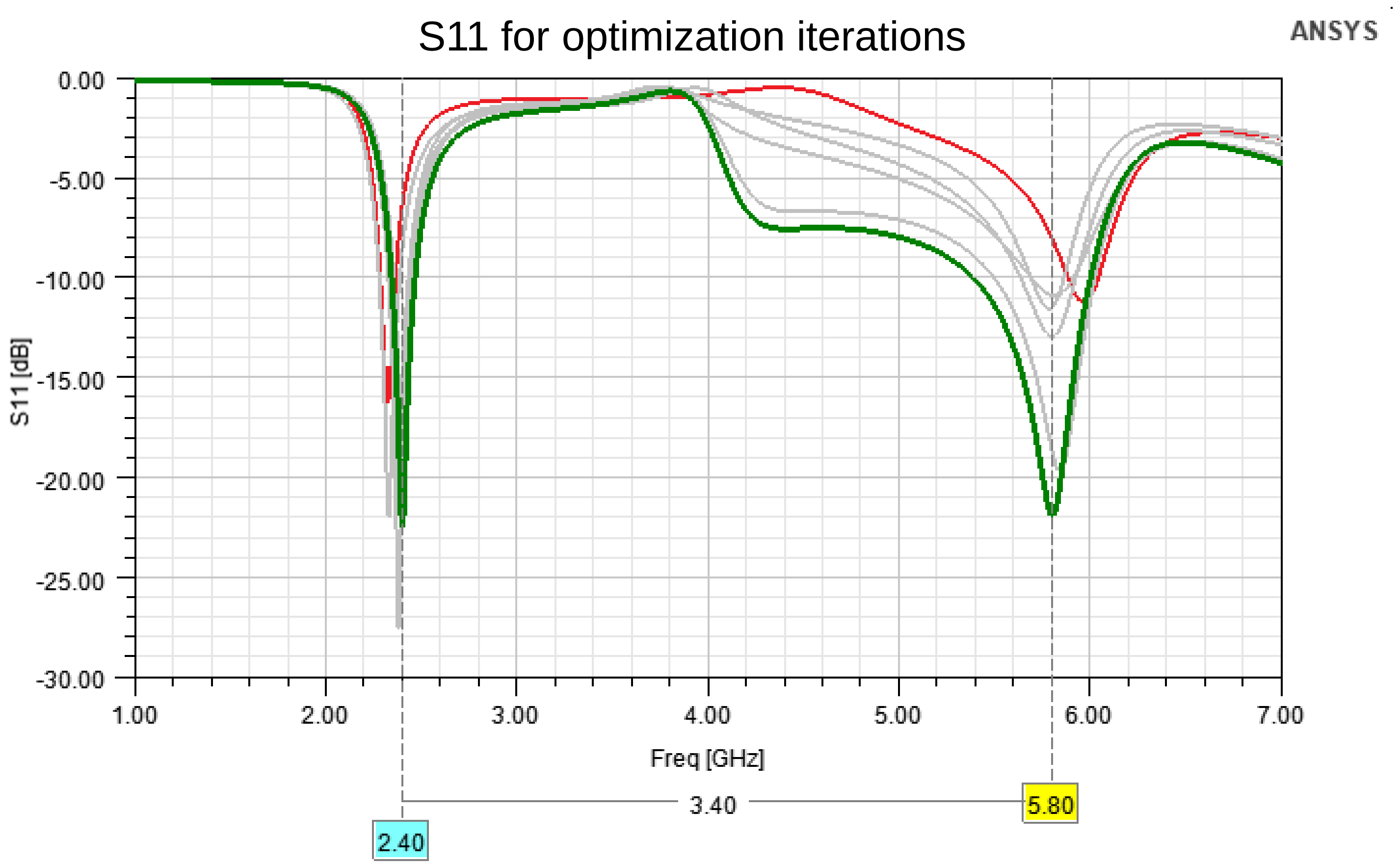


- Optimize <u>nine</u> geometry parameters:
  - Shift resonances to 2.4 and 5.8 GHz
  - S11 at those frequencies is required to be less than -20 dB

[1] Gai, S., Jiao, Y.C., Yang, Y.B., Li, C.Y. and Gong, J.G., 2010. Design of a novel microstrip-fed dual-band slot antenna for WLAN applications. *Progress In Electromagnetics Research*, *13*, pp.75-81.

Dual-band antenna optimization results

Iteration #6



- An optimum design is found in six iterations

Summary

- Reviewed HFSS
  - It can calculate partial derivatives of the antenna response with respect to the optimization parameters

- Antenna optimization workflow:
  - Use partial derivatives from HFSS to create a metamodel of the antenna response
  - optiSLang optimizes metamodel with NOA
  - Iterate optimization process to overcome inaccuracies in metamodel

- Illustrated functionality of iterative metamodel based optimization approach for a dual band antenna by varying nine geometry parameters

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Thanks !