COMPUTATIONALLY EFFICIENT SIMULATION-DRIVEN DESIGN TECHNIQUES FOR MICROWAVE ENGINEERING

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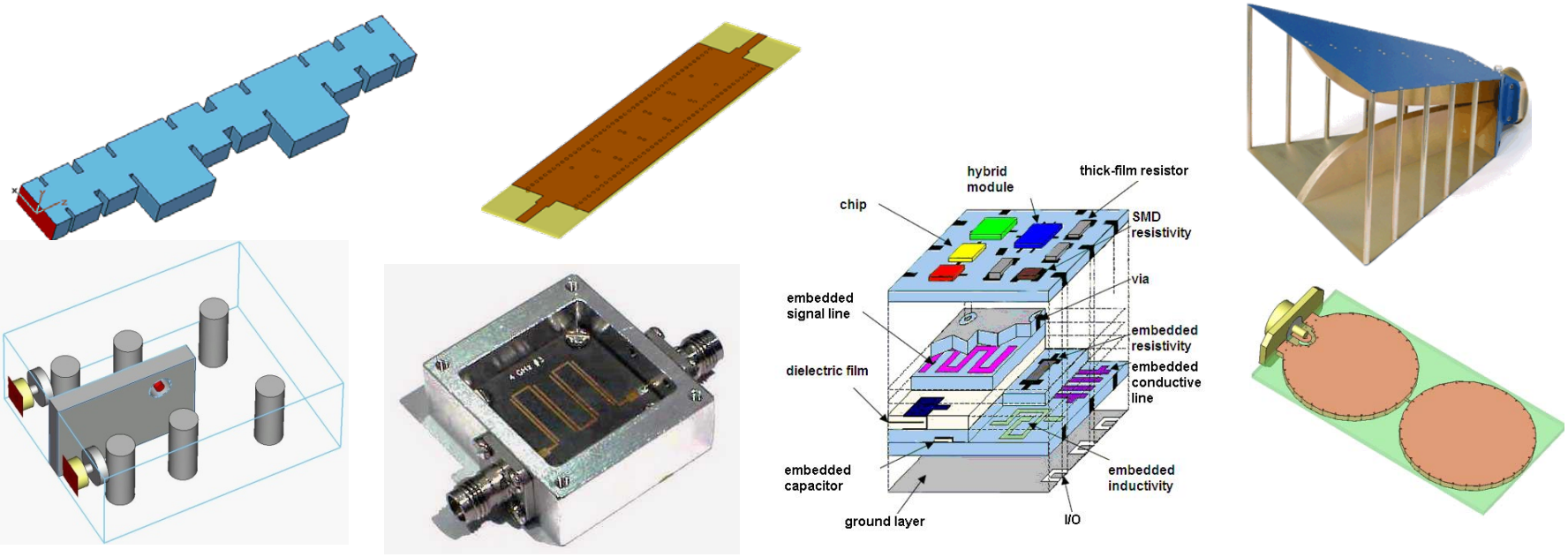
Challenges of Simulation-Driven Microwave Design

Contemporary microwave engineering relies more and more on CPU-intensive electromagnetic simulations

Accurate evaluation of typical components can be very time consuming: from several minutes to many hours per simulation



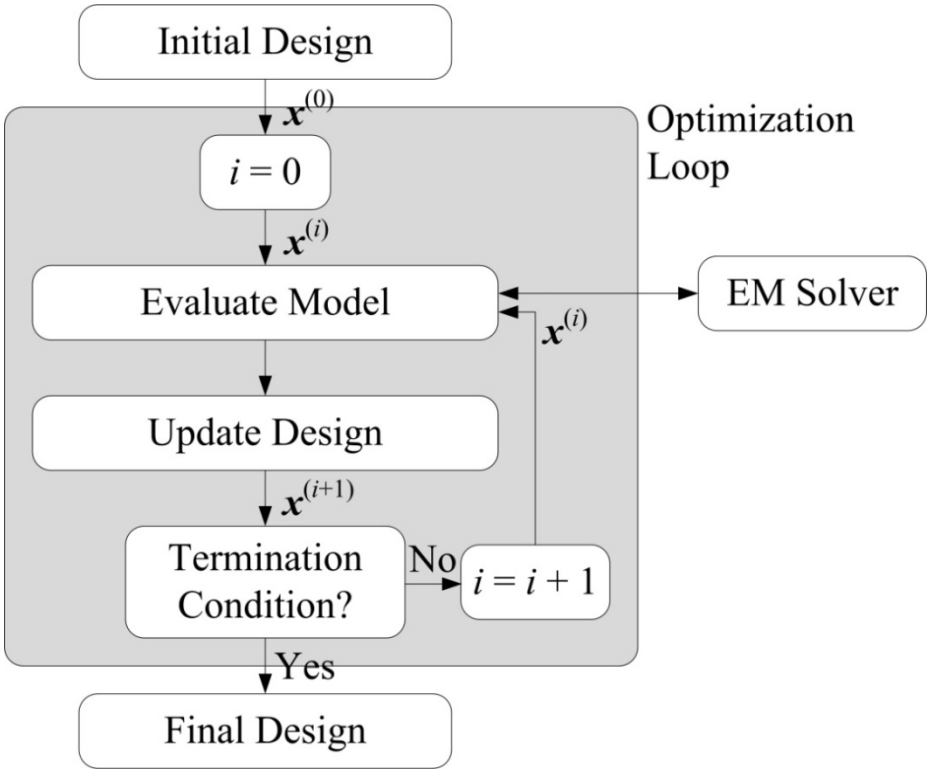
Typical microwave components: filters, SICs, LTCC, and antennas

Challenges of Simulation-Driven Microwave Design

Traditional design methods that employ EM solver in an optimization loop are impractical due to:

- High computational cost of EM simulation
- Poor analytical properties of EM-based objective functions
- Lack of sensitivity information or sensitivity expensive to compute

Traditional approach: EM solver directly employed in the optimization loop:
=> High CPU cost
=> Fails to find satisfactory design

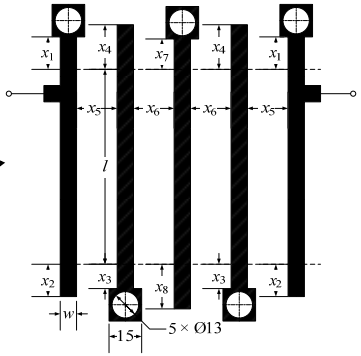


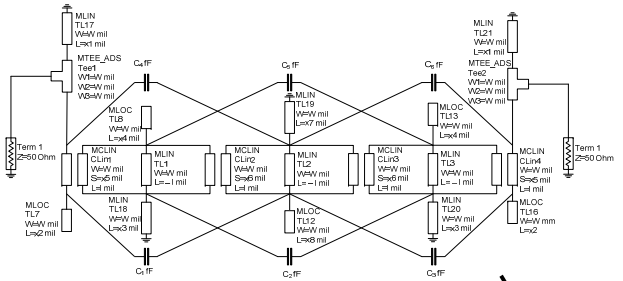
Surrogate-Based Microwave Design

Computationally efficient simulation-driven design can be realized using physically-based surrogate models

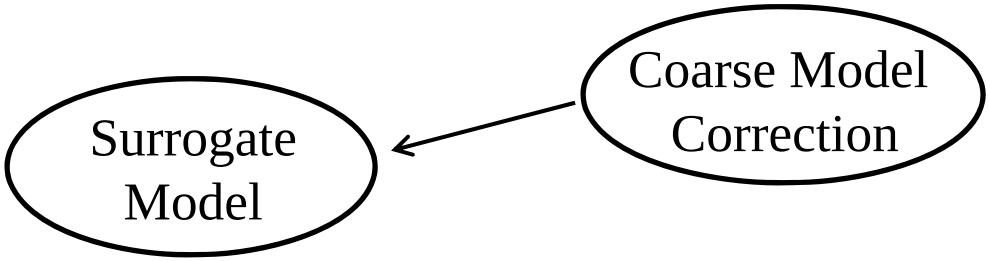
Key components:

- High-fidelity (fine) model: CPU-intensive EM-simulated microwave structure
- Low-fidelity (coarse) model: low-cost but physically-based representation (e.g., equivalent circuit)





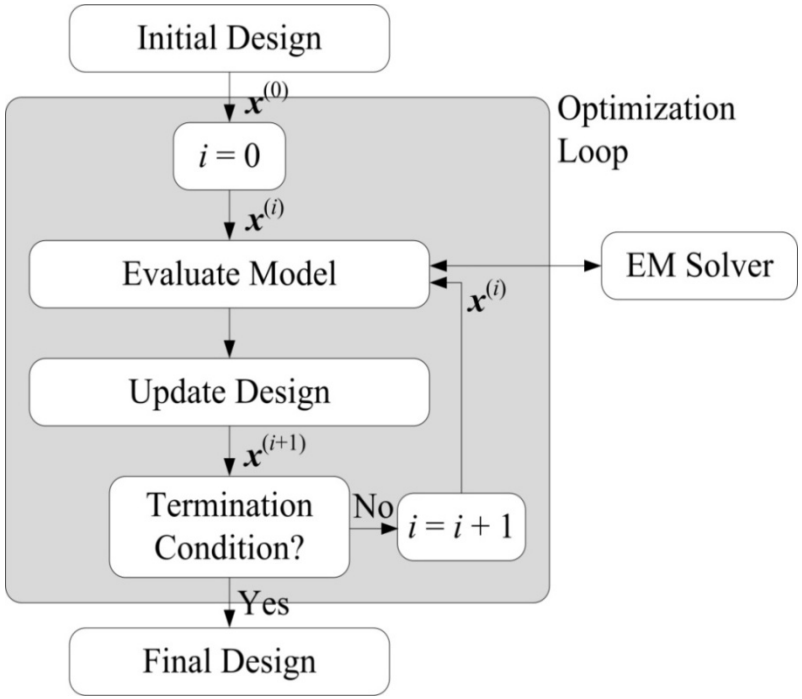
Coarse model is very fast but usually lacks accuracy; To serve as a surrogate, it has to be corrected



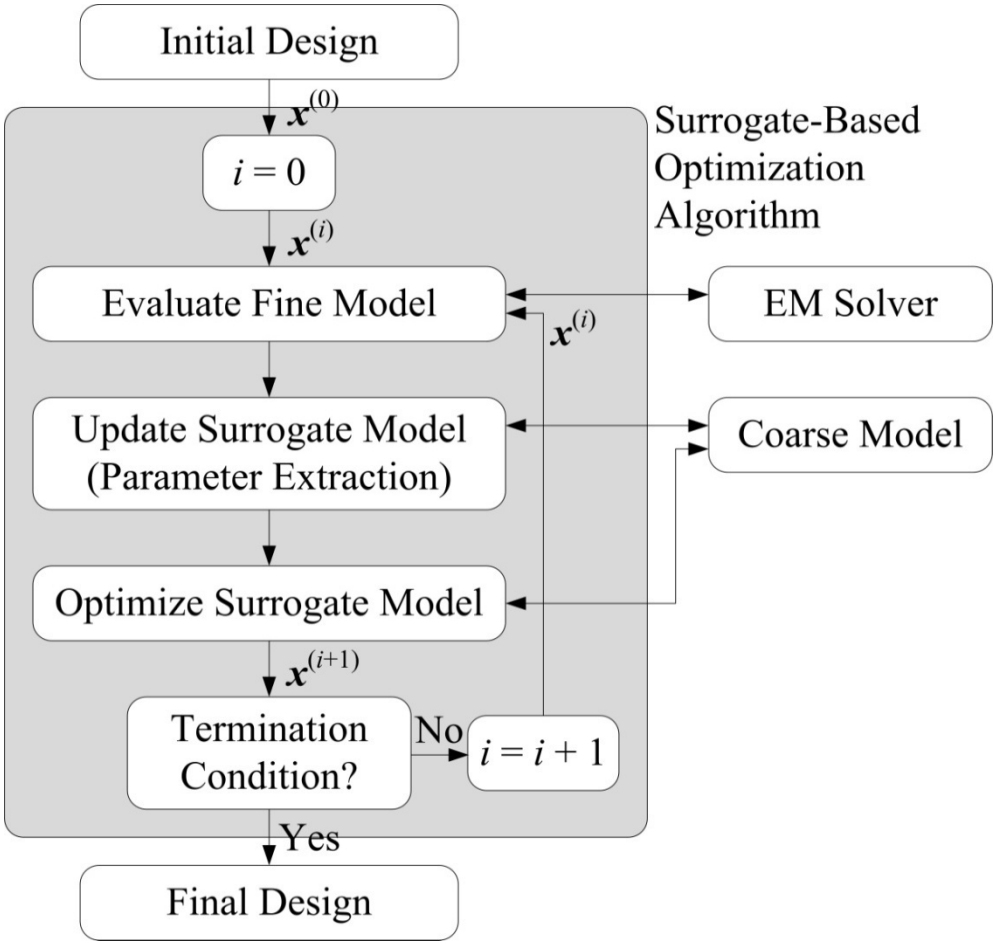
Surrogate-Based Microwave Design

Surrogate-based design replaces direct optimization of the fine model by iterative re-optimization and updating of the surrogate:

Traditional approach



Surrogate-Based

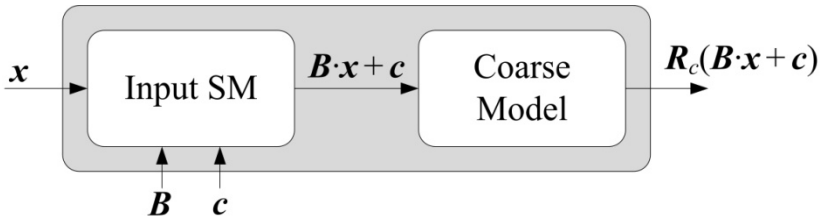


Surrogate-Based Microwave Design: Space Mapping

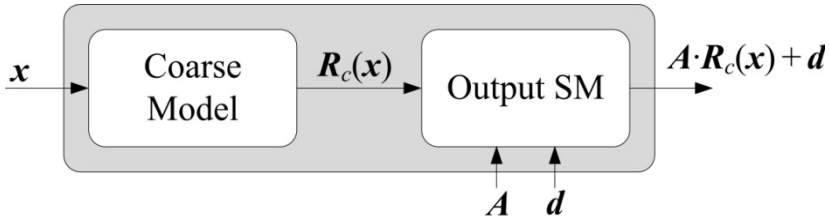
Probably the most successful surrogate-based design technique in microwave engineering is space mapping (SM)

Coarse model correction methods used by SM:

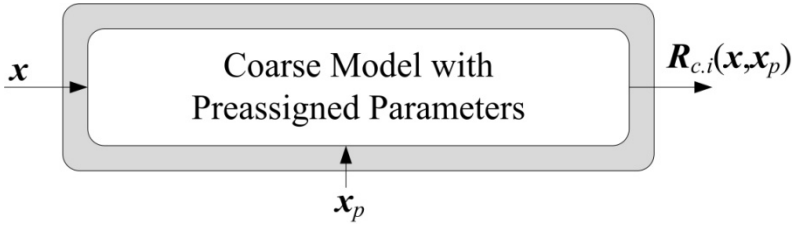
(a) Domain distortion (input SM)



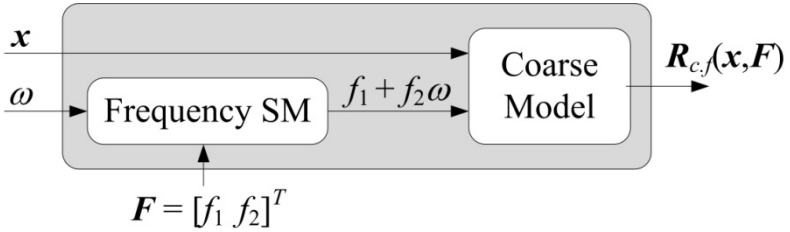
(b) Response distortion (output SM)



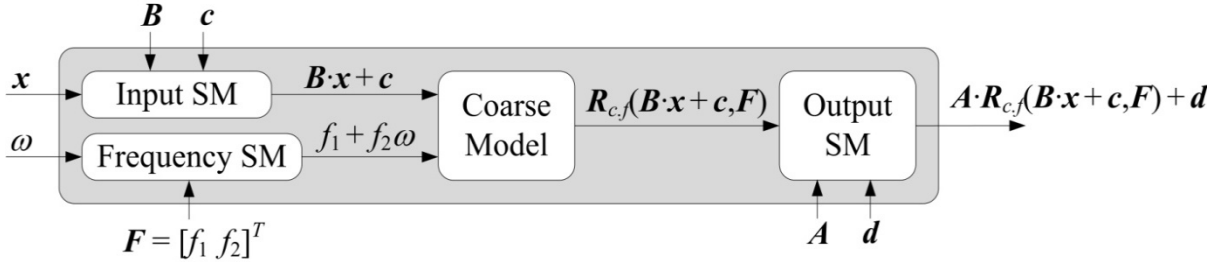
(c) Exploiting physically-based degrees of freedom (implicit SM)



(d) Exploiting free parameters (frequency SM)

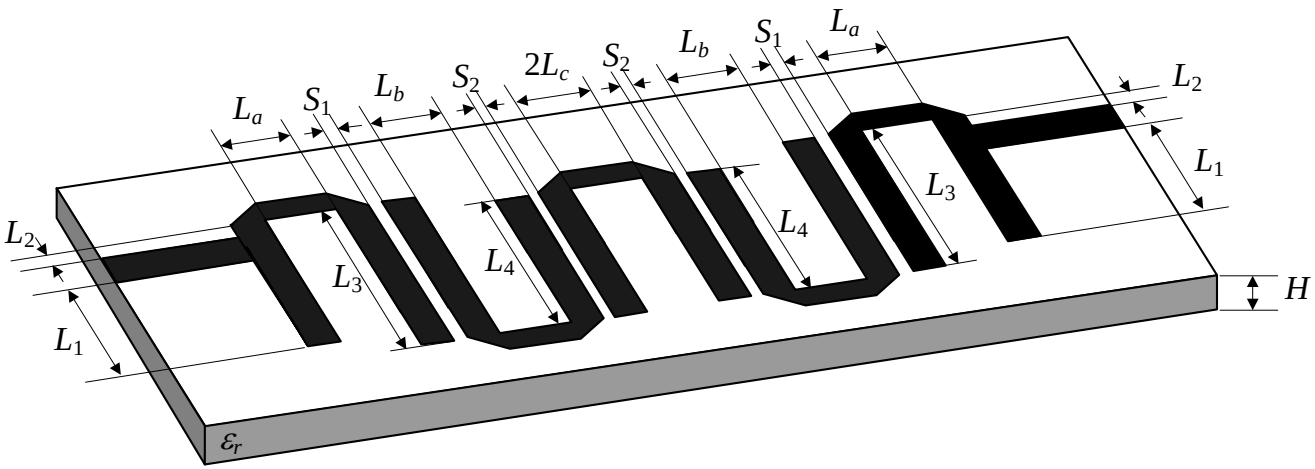


Example of combined SM surrogate model:

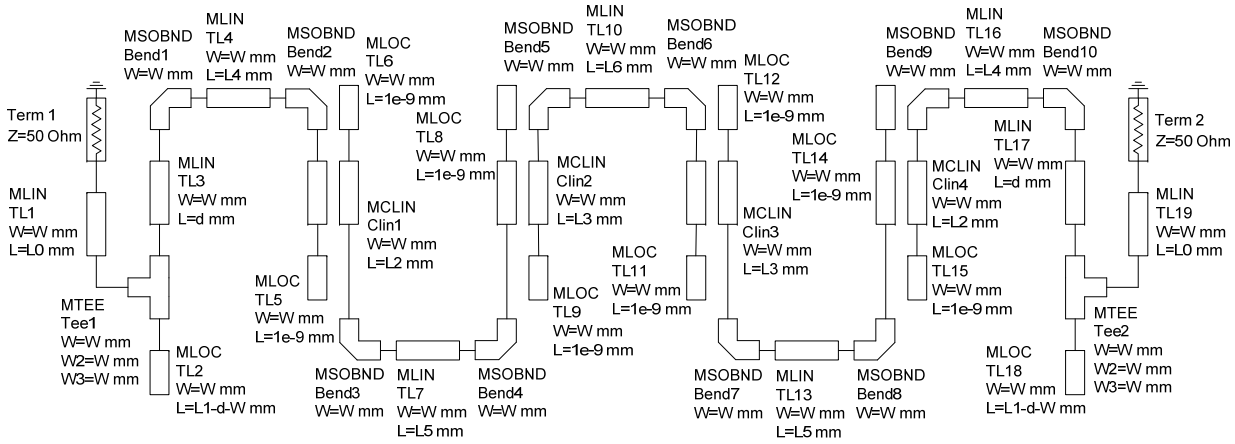


Example: Design of Microstrip Hairpin Filter

Fine model: Simulation time 17 hours per design!



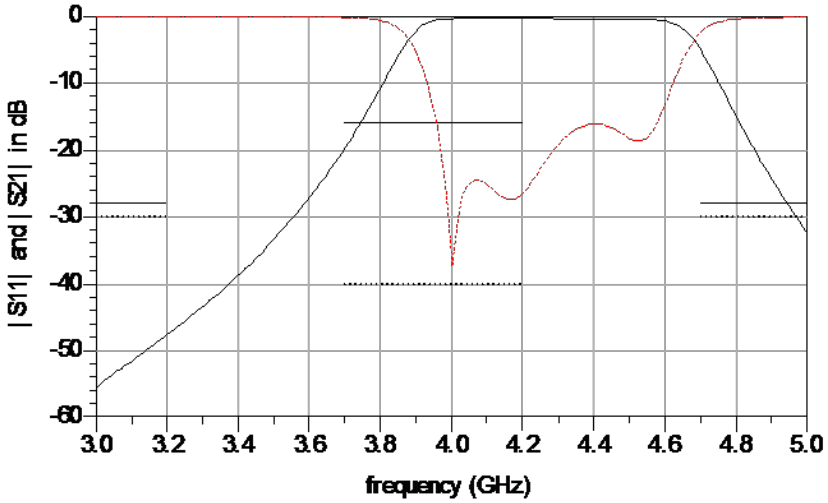
Coarse model: Equivalent circuit – simulation time less than 0.1 s



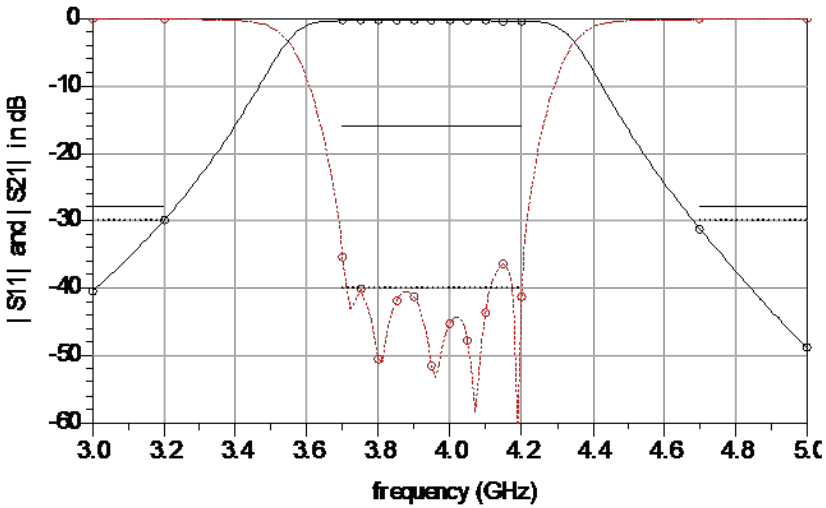
Example: Design of Microstrip Hairpin Filter

Traditional design methods fail for this example

Space Mapping: Optimal design obtained after 5 EM simulations!



Initial responses and design specifications

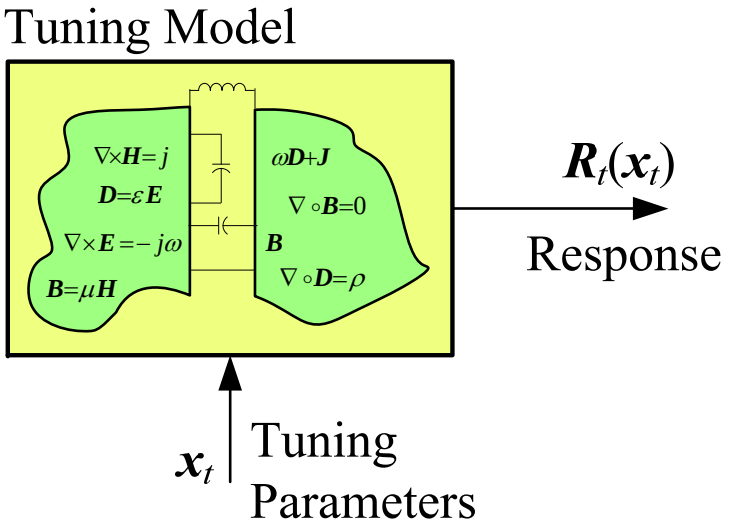


Responses of the optimized filter

Simulation-Based Tuning

Design process can be performed in an even more efficient way using the concept of tuning

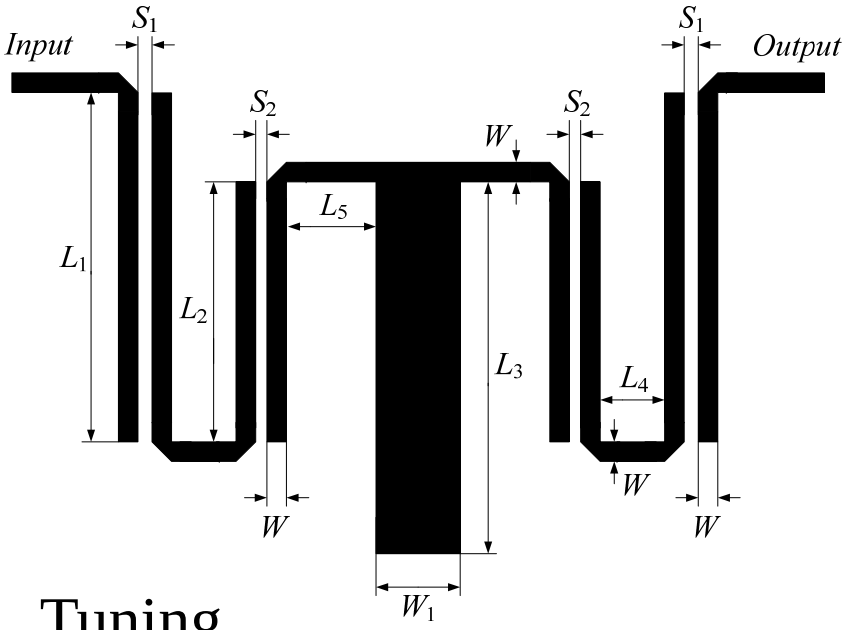
Simulation-based tuning is an invasive technique, where the structure under consideration is "cut" and the circuit-based tuning components are inserted



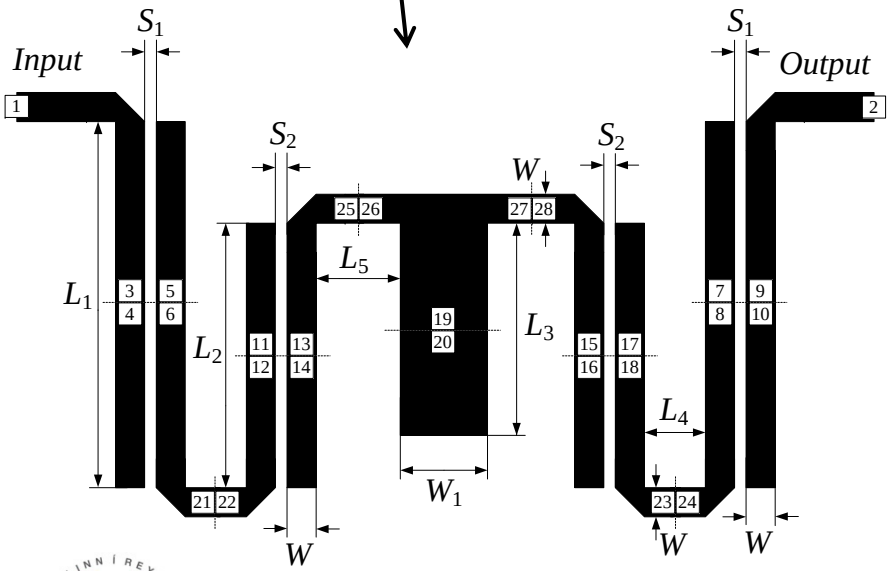
The resulting surrogate ("tuning" model) is very fast and yet accurate as it contains the "image" of the fine model at the initial design

Example: Chebyshev Filter

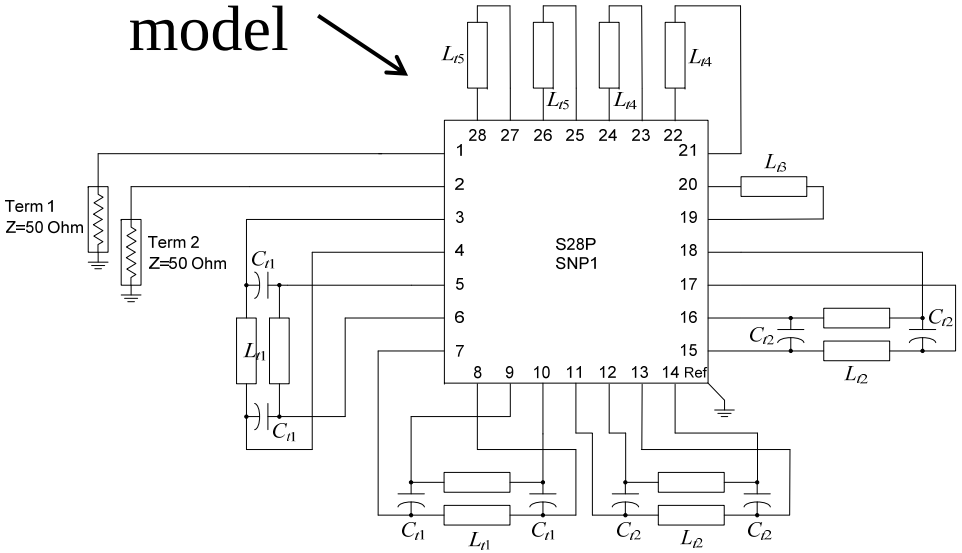
Chebyshev filter geometry →



Fine model with places for inserting the tuning ports

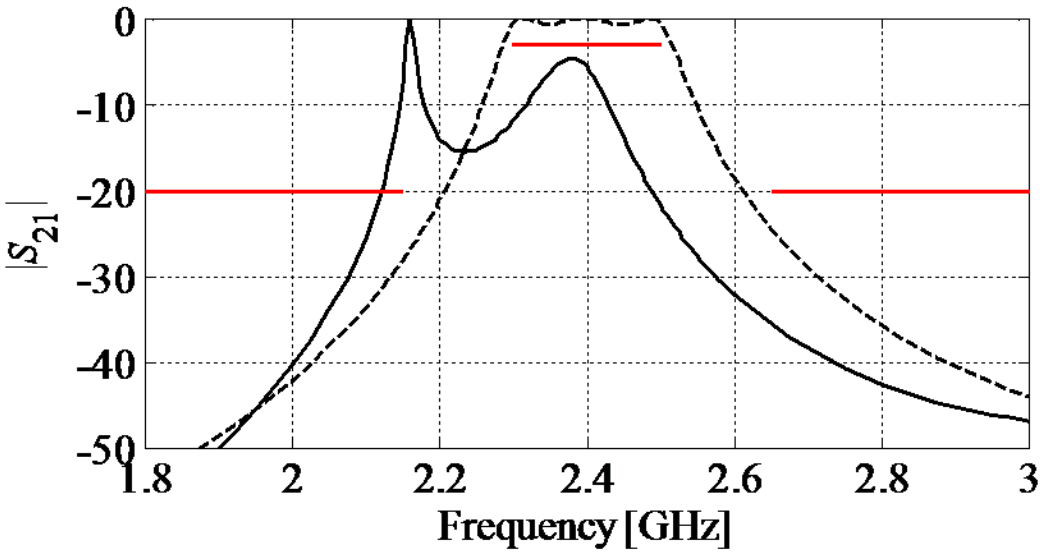


Tuning model →

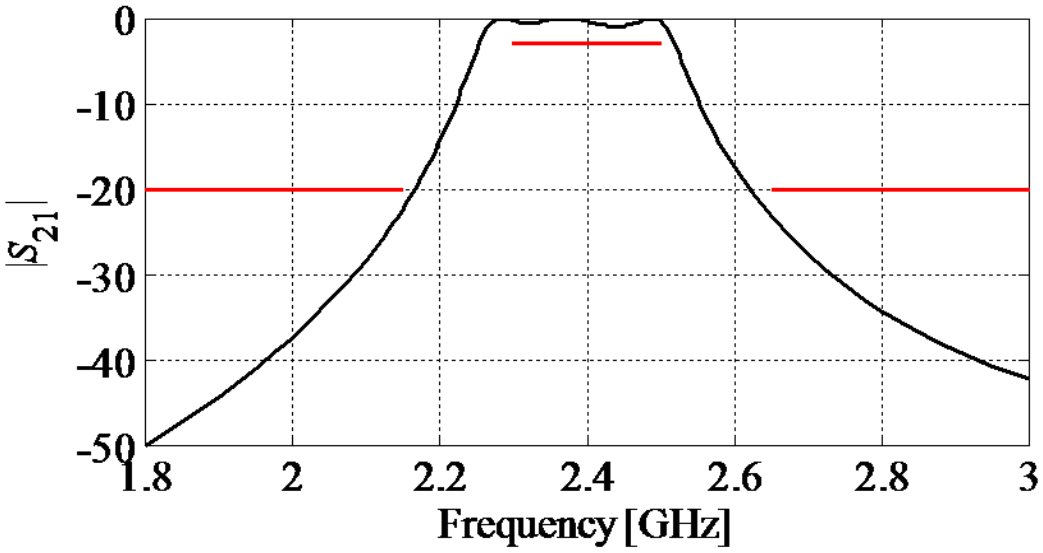


Example: Chebyshev Filter

The coarse (dashed line) and fine model (solid line) response at the initial design:



Fine model response after one (!) iteration of the tuning-based optimization algorithm:



Engineering Optimization & Modeling Center (EOMC)

EOMC develops surrogate-based techniques for computationally expensive real-world engineering design problems

Applications: microwave/RF engineering, aerospace design, aeroacoustics, hydrodynamics, oil industry

Website: http://www.ru.is/kennarar/koziel/eoml_index.html