



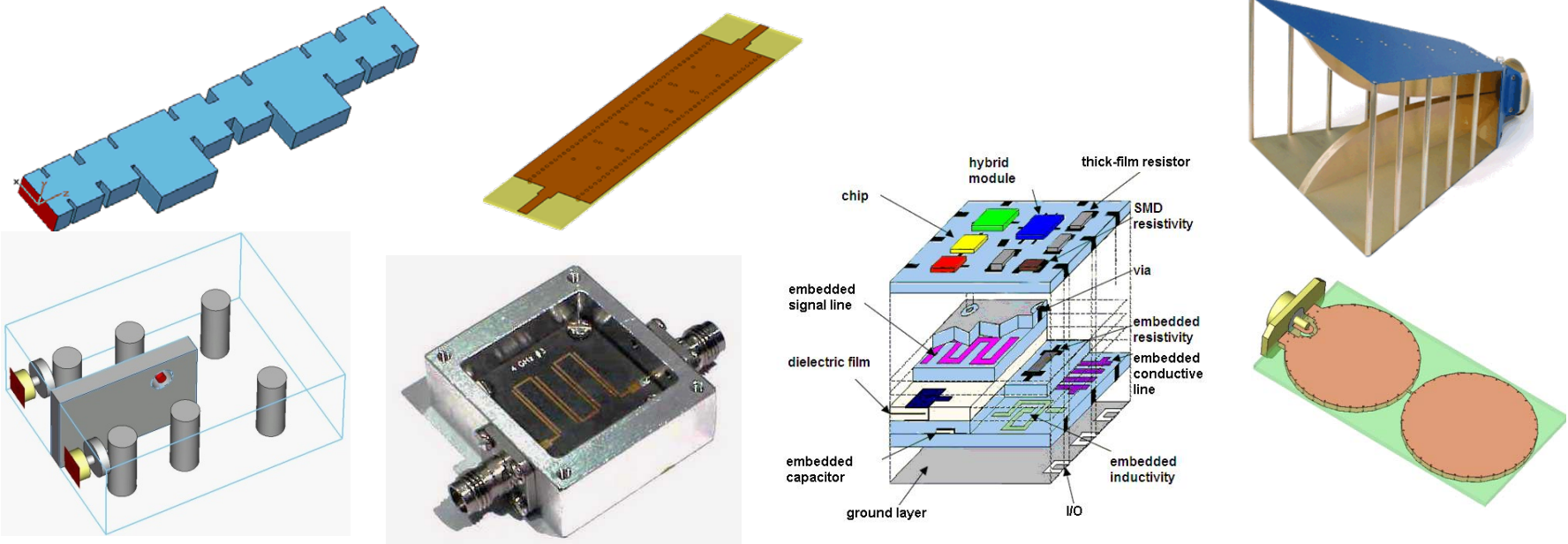
# **COMPUTATIONALLY EFFICIENT SIMULATION-DRIVEN DESIGN TECHNIQUES FOR MICROWAVE ENGINEERING**

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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

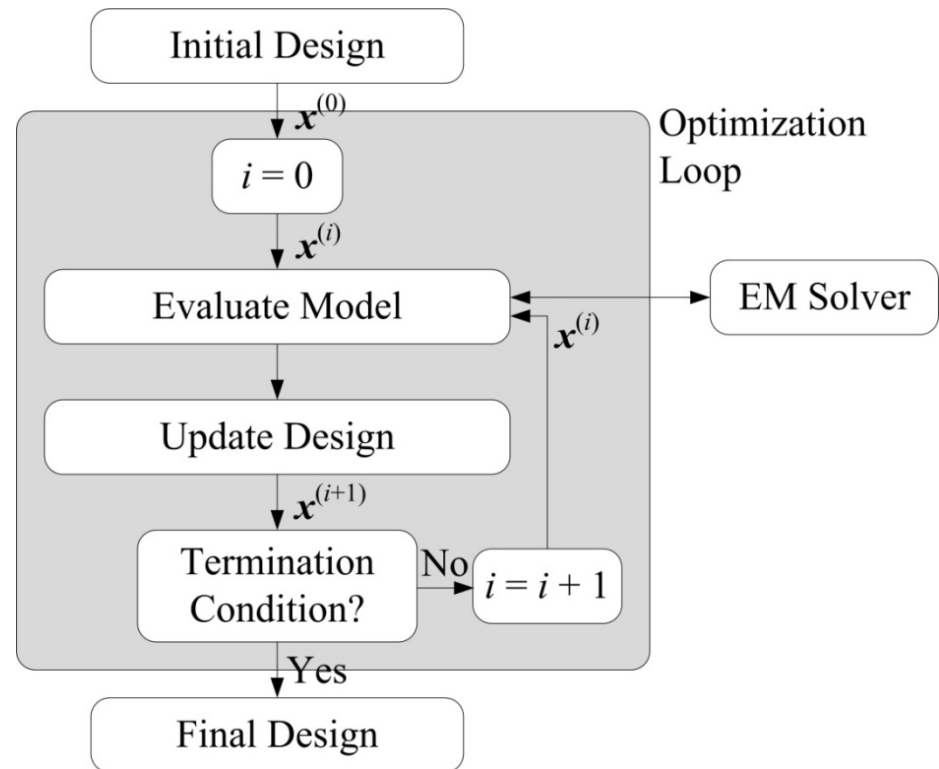
Traditional design methods that employ EM solver in an optimization loop are impractical due to:

- 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



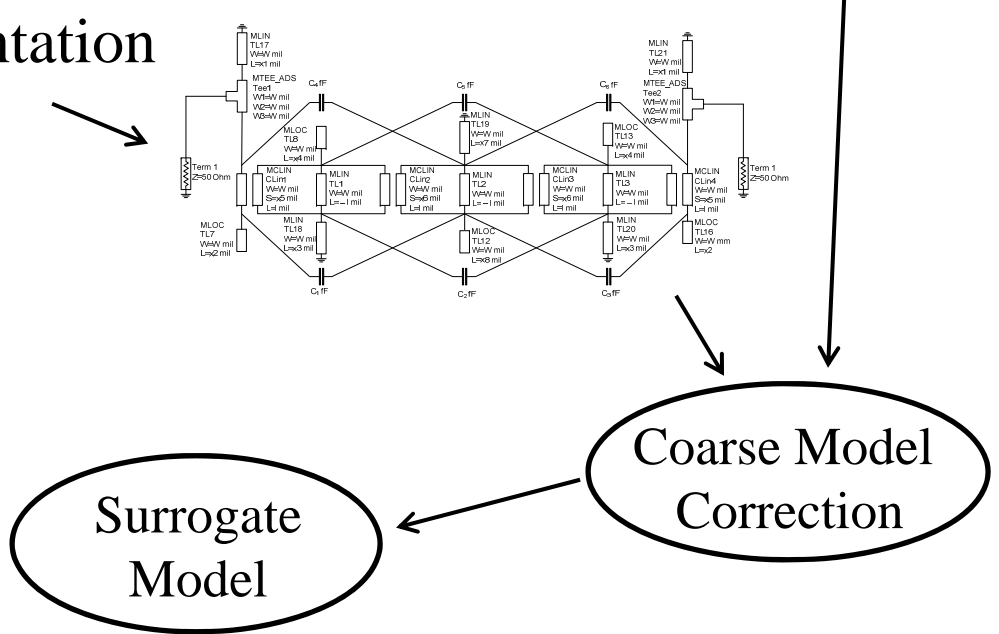
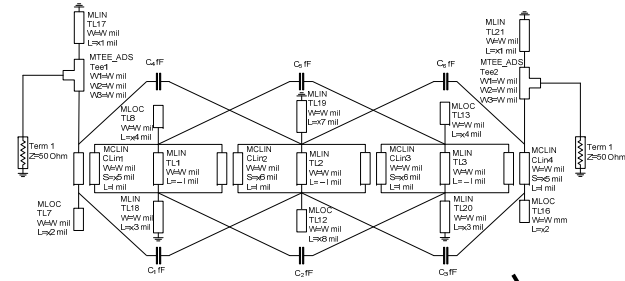
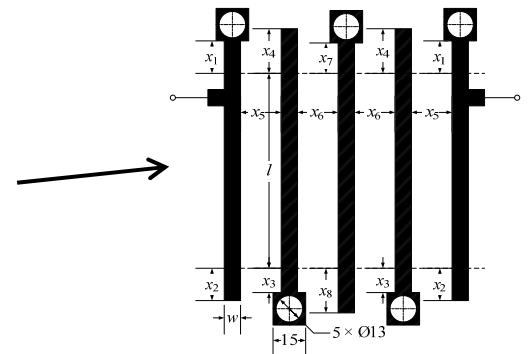
# Surrogate-Based Microwave Design

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)

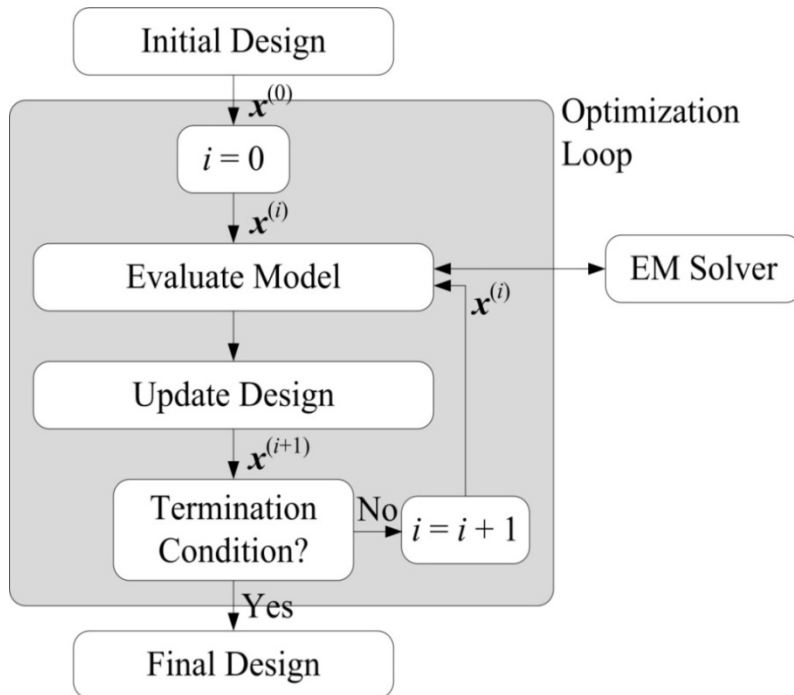
Coarse model is very fast but usually lacks accuracy; To serve as a surrogate, it has to be corrected



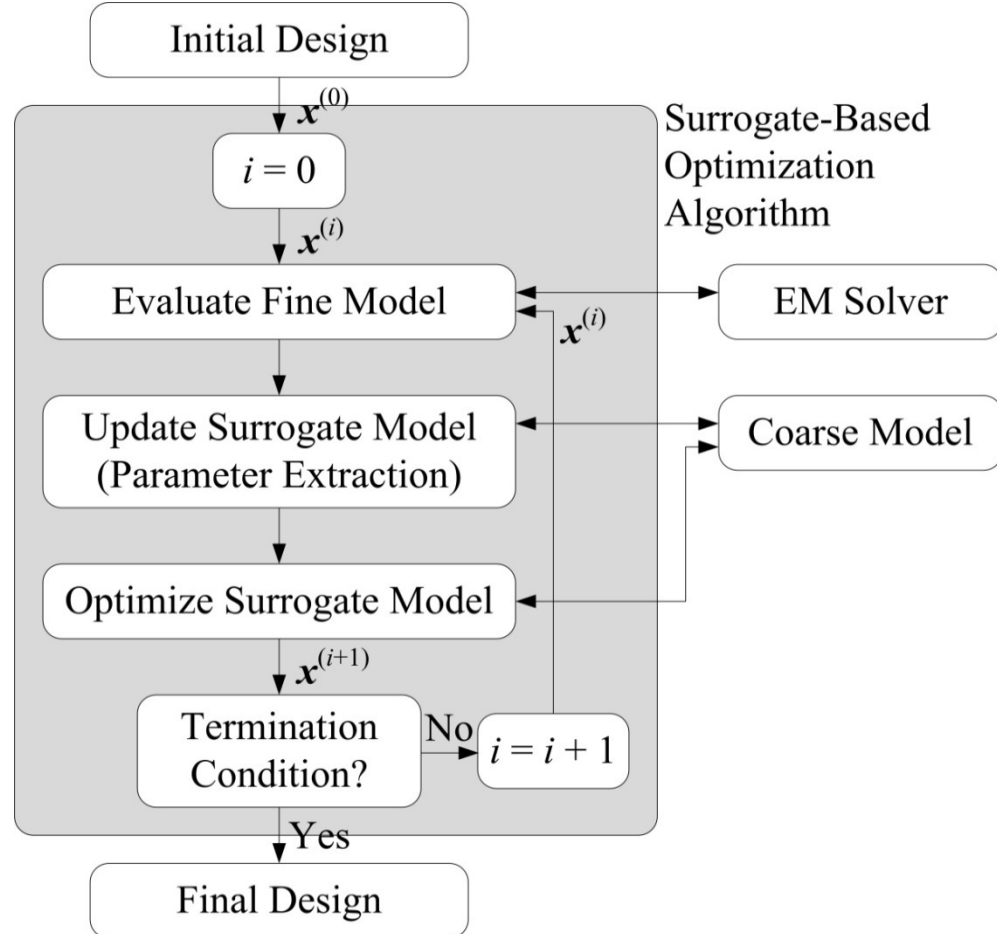
# Surrogate-Based Microwave Design

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

## Traditional approach



## Surrogate-Based

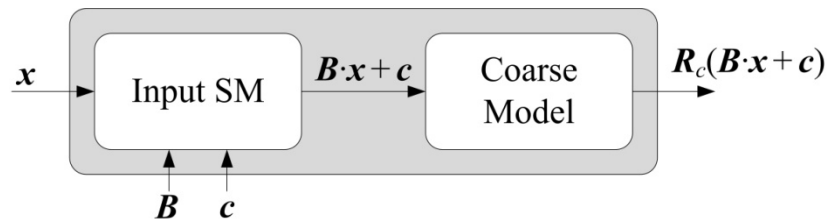


# Surrogate-Based Microwave Design: Space Mapping

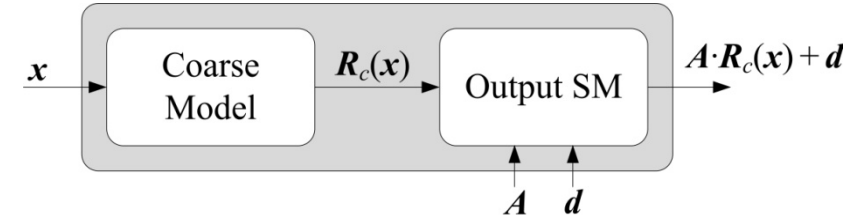
Probably the most successful surrogate-based design technique in microwave engineering is space mapping (SM)

Coarse model correction methods used by SM:

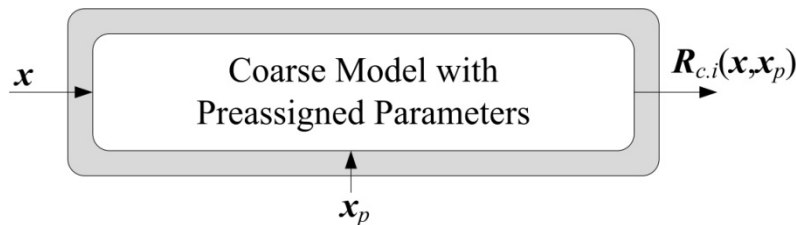
(a) Domain distortion (input SM)



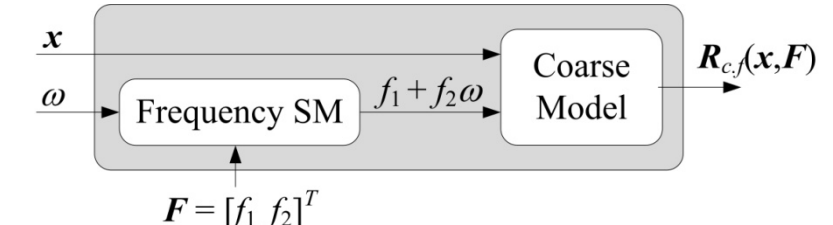
(b) Response distortion (output SM)



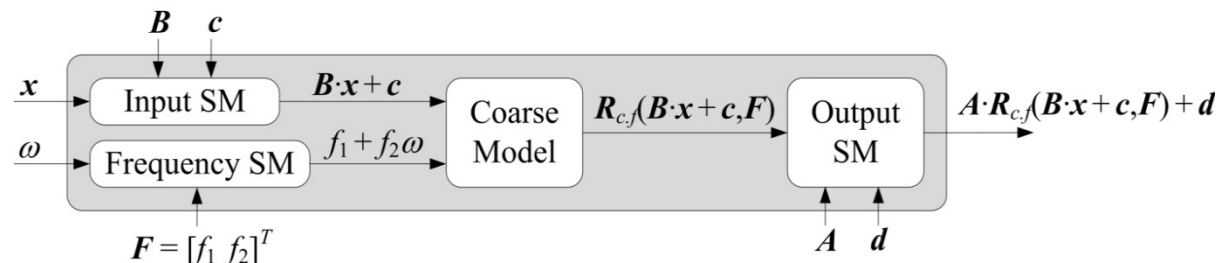
(c) Exploiting physically-based degrees of freedom (implicit SM)



(d) Exploiting free parameters (frequency SM)

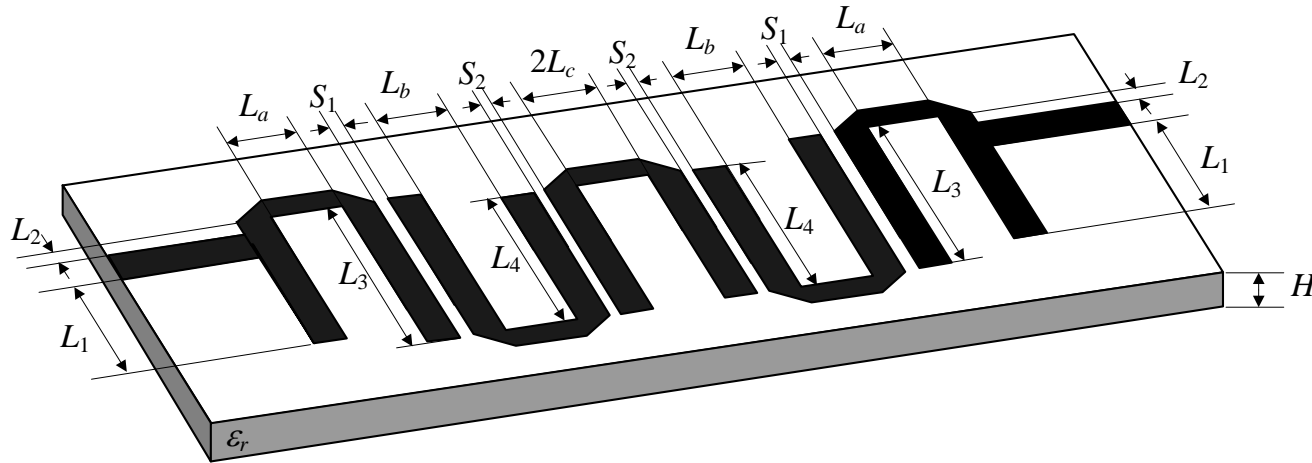


Example of combined SM surrogate model:

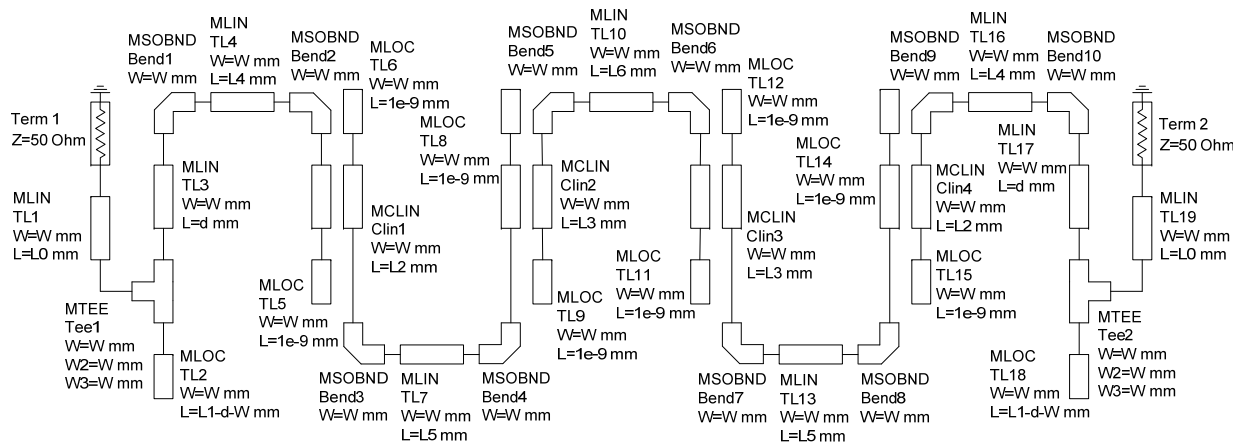


# Example: Design of Microstrip Hairpin Filter

Fine model: Simulation time 17 hours per design!



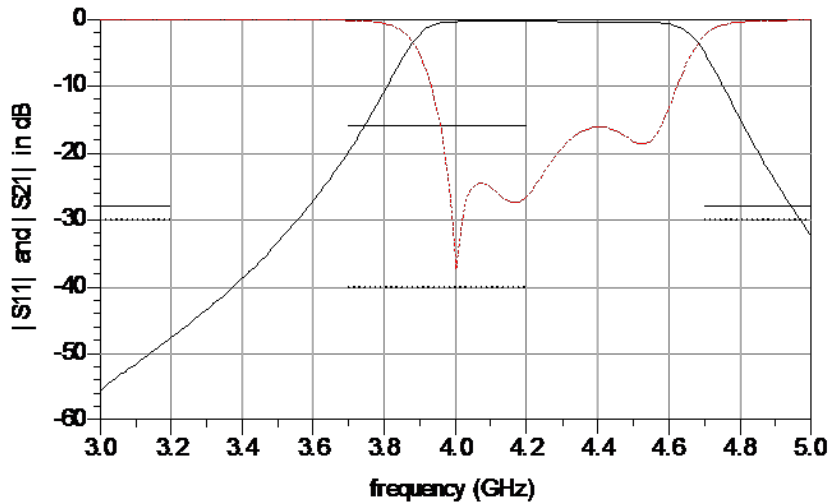
Coarse model: Equivalent circuit – simulation time less than 0.1 s



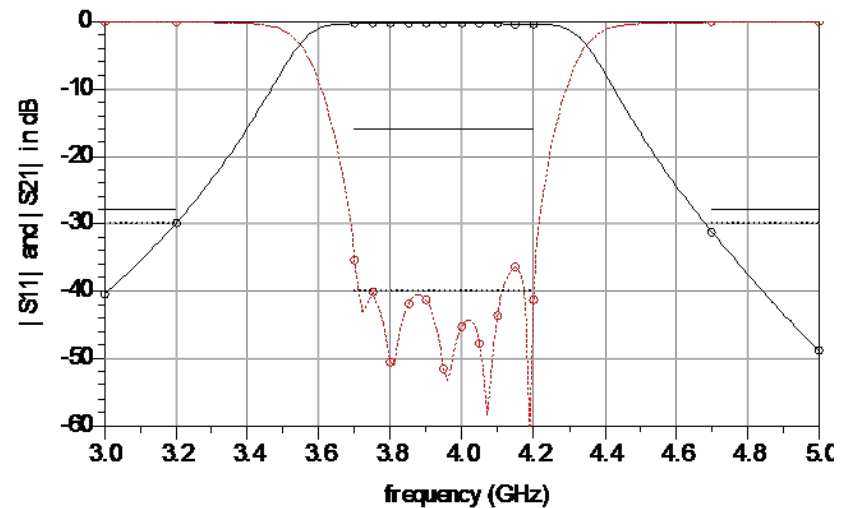
# Example: Design of Microstrip Hairpin Filter

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

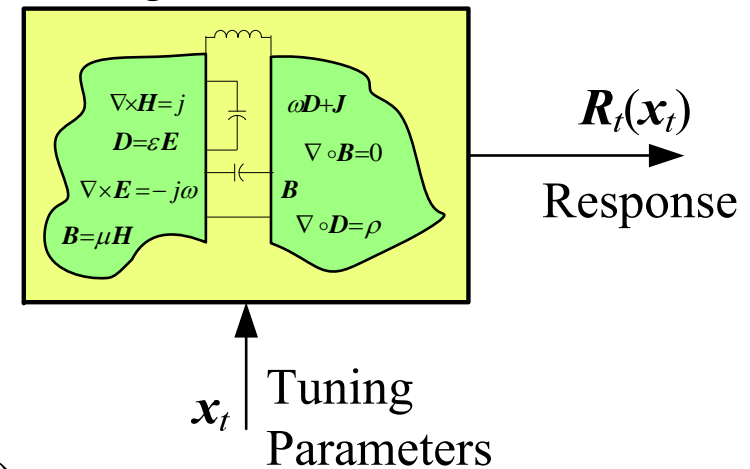
# Simulation-Based Tuning

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

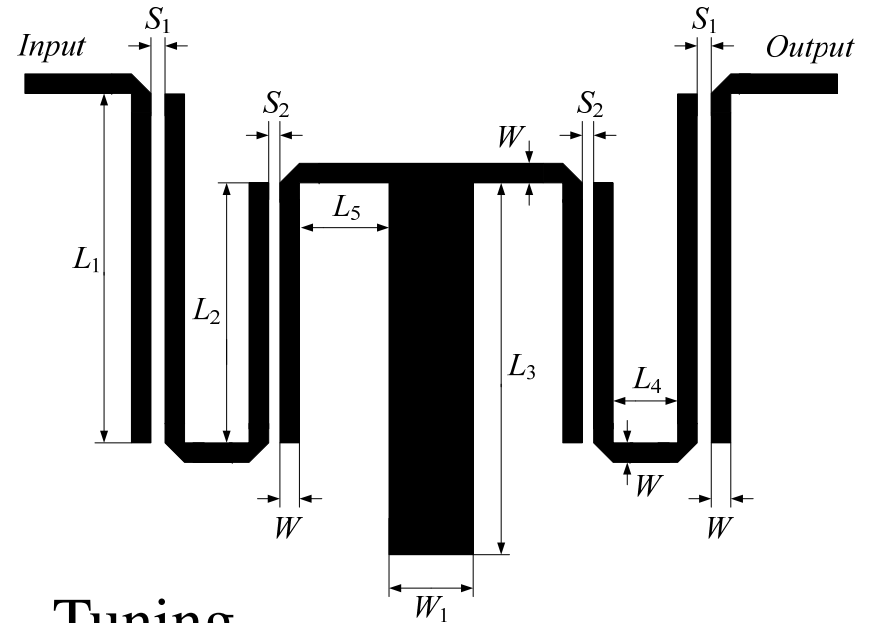
Tuning Model



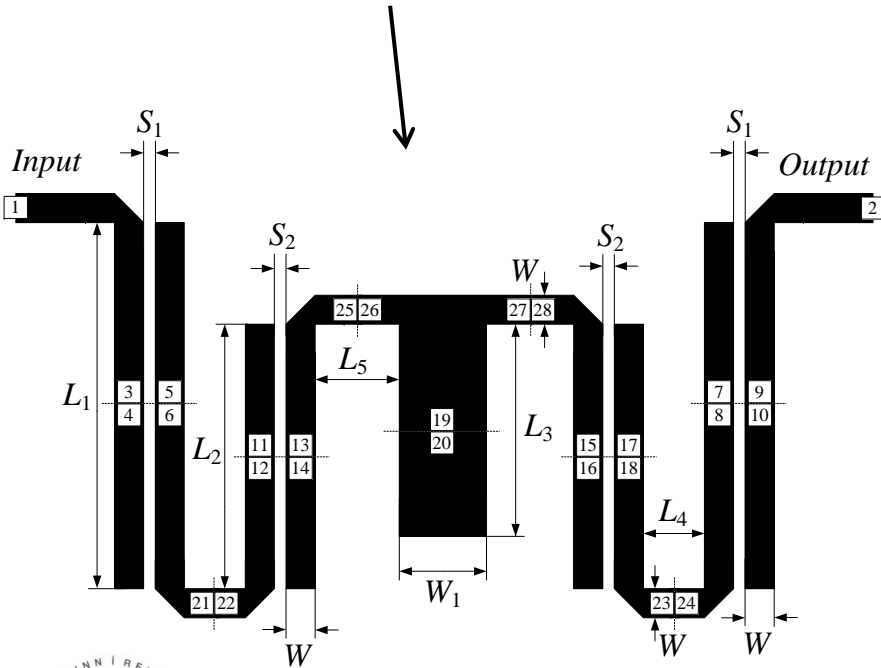
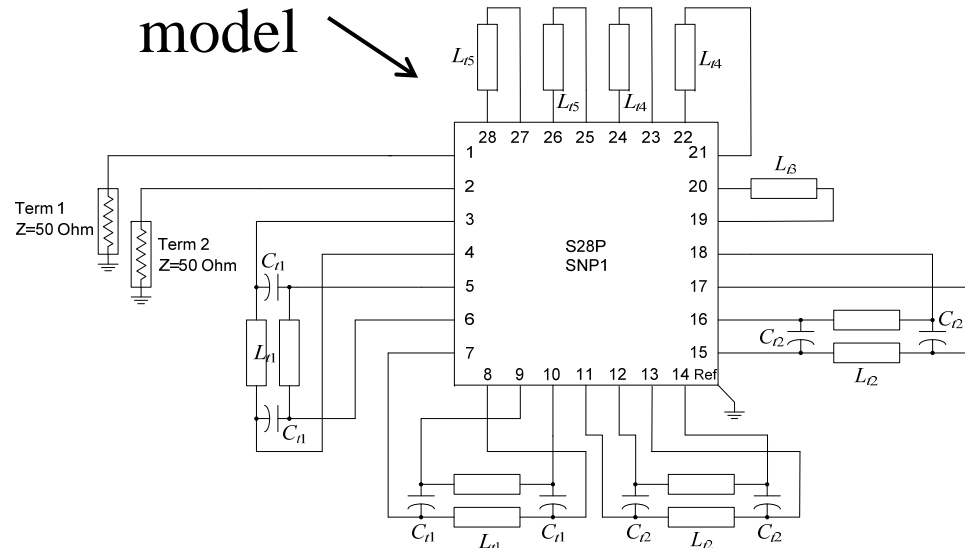
# Example: Chebyshev Filter

Chebyshev filter geometry →

Fine model with places for inserting the tuning ports

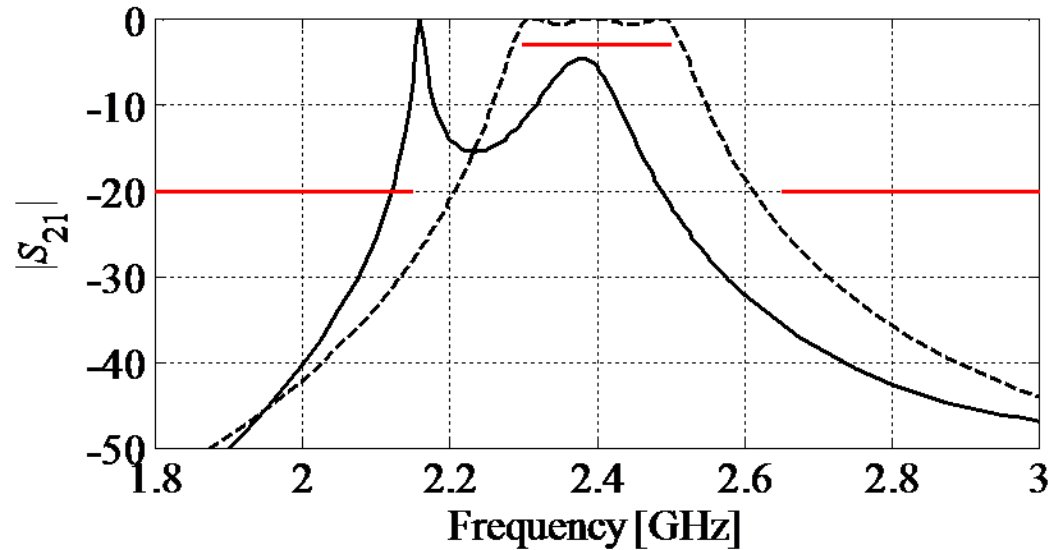


Tuning model →

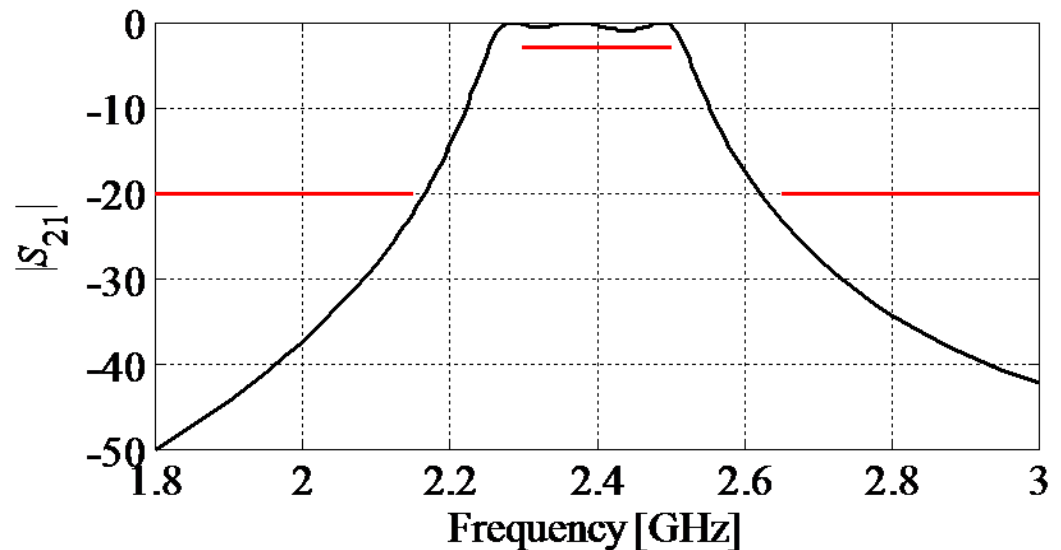


# Example: Chebyshev Filter

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](http://www.ru.is/kennarar/koziel/eoml_index.html)

## EOMC People

### Faculty



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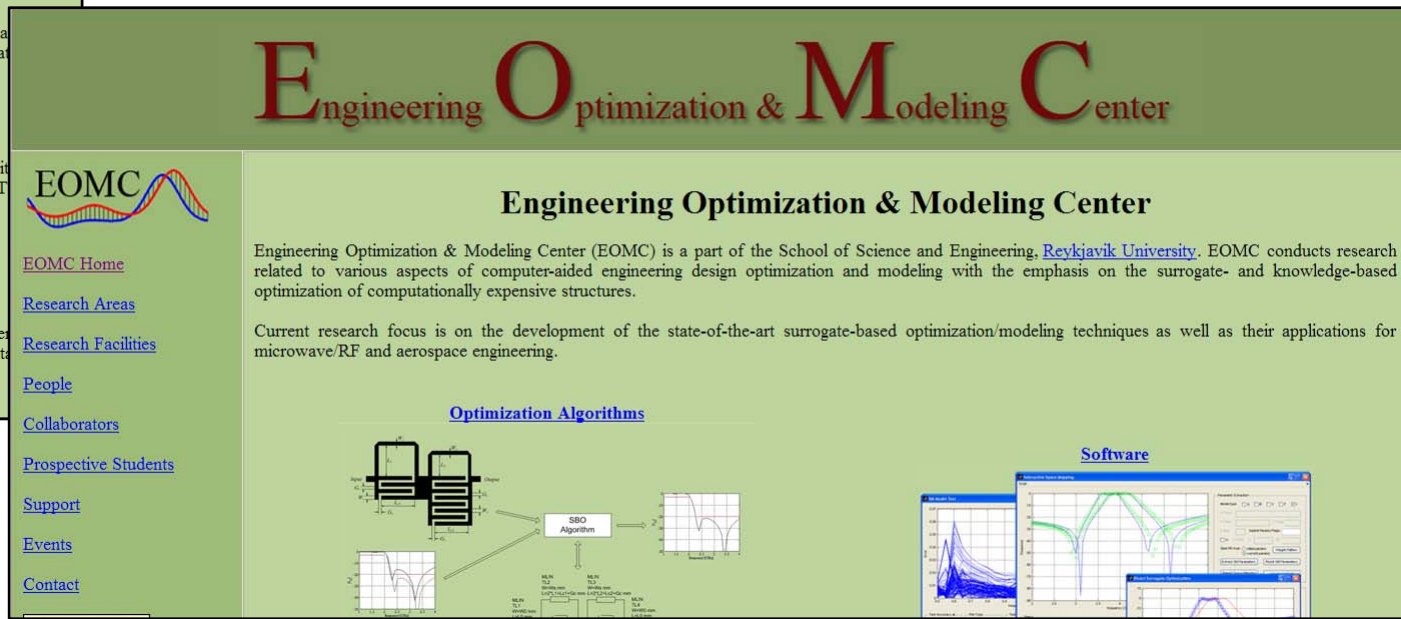


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The screenshot shows the EOMC website homepage. At the top, the full name "Engineering Optimization & Modeling Center" is displayed in large, stylized letters. Below this, the EOMC logo is visible. The main content area features a paragraph describing the center's research focus on surrogate-based optimization and modeling for computationally expensive structures. A secondary paragraph details the current research focus on state-of-the-art surrogate-based optimization and modeling techniques for microwave/RF and aerospace engineering. The page includes a navigation menu on the left with links for EOMC Home, Research Areas, Research Facilities, People, Collaborators, Prospective Students, Support, Events, and Contact. On the right, there are sections for "Optimization Algorithms" and "Software", each accompanied by a diagram or image of software interfaces. The "Optimization Algorithms" section shows a flowchart of the SBO (Surrogate-Based Optimization) process, while the "Software" section displays several plots and graphs from optimization software.