Expanded Space Mapping Design Framework Exploiting Preassigned Parameters

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outline

- coarse model calibration
- Key Preassigned Parameters (KPP)
- coarse model decomposition
- Expanded Space Mapping Design Framework (ESMDF) algorithm
- examples
- conclusions

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Coarse Model Calibration Techniques

in space mapping *(Bandler et al., 1994-2001)*
this calibration is performed by means of
design parameter space transformation

Ye and Mansour *(1997)* enhanced models by adding
elements to nonadjacent components

here we calibrate the coarse model by exploiting
preassigned parameters

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Key Preassigned Parameters (KPP)

the KPP are assumed to be non-optimizable

examples: dielectric constant, substrate height, etc.

the coarse model is very sensitive to KPP

the coarse model is calibrated to match the fine model by tuning the KPP

our algorithm establishes a mapping from some optimizable parameters to KPP

the mapping is updated iteratively

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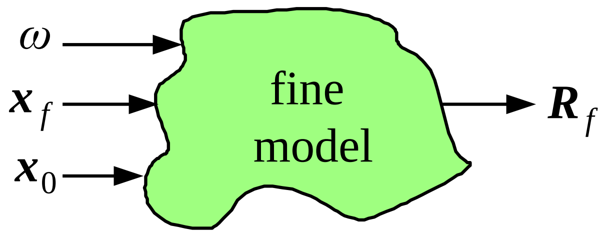

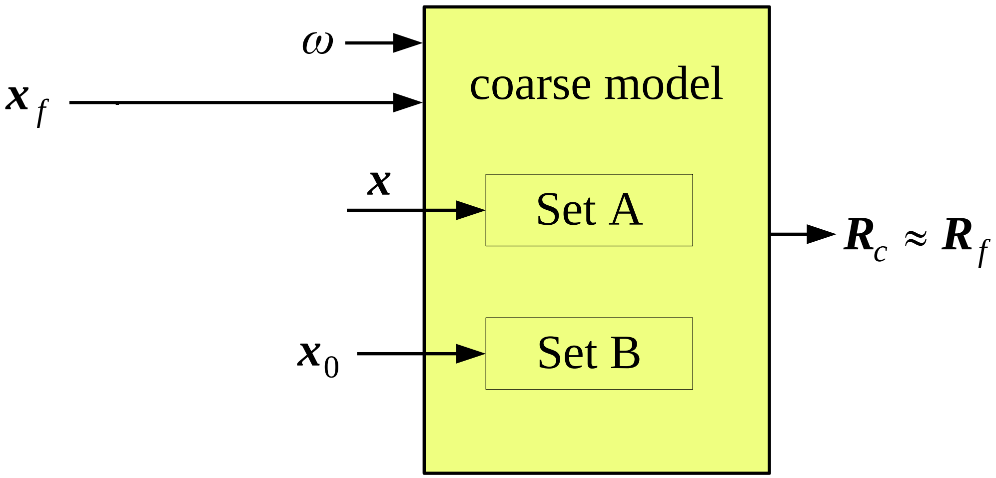

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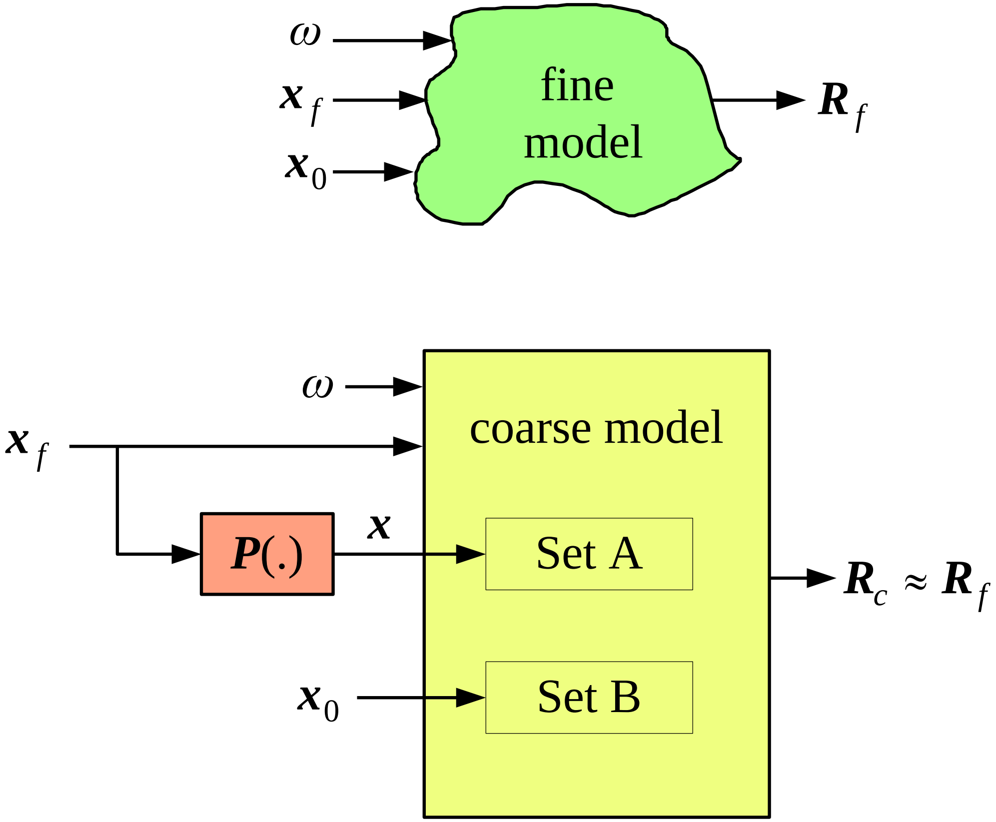
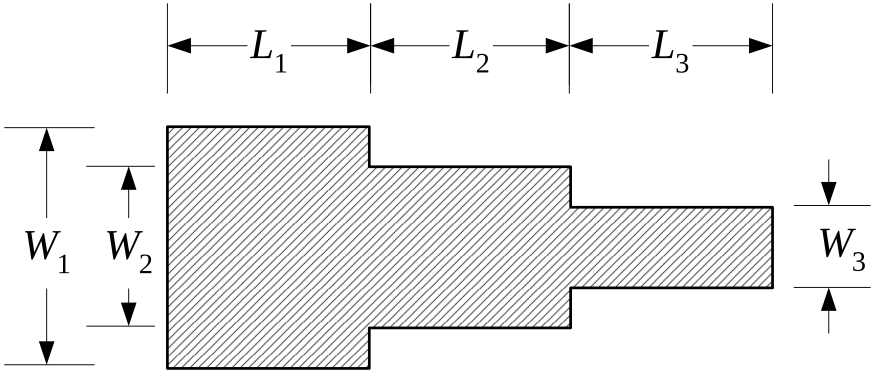


$$\boldsymbol{x} = \boldsymbol{P}(\boldsymbol{x}_r)$$

$$\boldsymbol{x}_f = [\boldsymbol{x}_r^T \quad \boldsymbol{x}_s^T]^T$$

$$\boldsymbol{x} = \boldsymbol{c} + \boldsymbol{B}_r \; \boldsymbol{x}_r$$

3:1 Microstrip Transformer



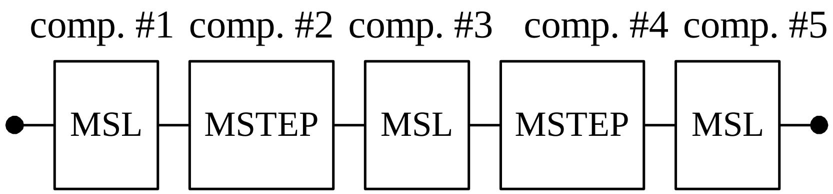
$$\boldsymbol{x}_f = [W_1 \quad W_2 \quad W_3 \quad L_1 \quad L_2 \quad L_3]^T$$

$$\boldsymbol{x}_r = [W_1 \quad W_2 \quad W_3]^T$$

$$\boldsymbol{x} = [\boldsymbol{x}_1^T \;\; \boldsymbol{x}_3^T \;\; \boldsymbol{x}_5^T\,]^T \qquad \boldsymbol{x}_i = [\varepsilon_{ri} \quad H_i\,]^T$$

$$\boldsymbol{x} = \boldsymbol{c} + \boldsymbol{B}_r\, \boldsymbol{x}_r$$

$\varepsilon_r = 9.7,\;\; H = 25$ mil



Coarse Model Decomposition

$\boldsymbol{x}_i$ represents the KPP of the ith component, $i \in I = \{1,2,\ldots, N\}$

N is the number of coarse model components

Set A: contains “relevant” coarse model components

Set B: contains coarse model components for which the coarse model is insensitive to their KPP

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Set A: contains "relevant" coarse model components

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Coarse Model Decomposition

Step 1 for all $i \in I = \{1,2,\ldots,N\}$ evaluate

$$S_i = \left\| \left(\frac{\partial \boldsymbol{R}_c^{\mathrm{T}}}{\partial \boldsymbol{x}_i} \boldsymbol{D} \right)^{\mathrm{T}} \right\|_F , \quad \boldsymbol{D} = \mathrm{diag}(\boldsymbol{x}_0)$$

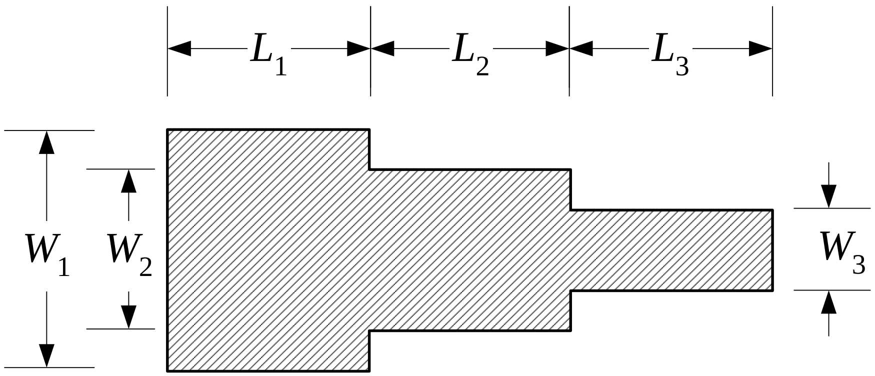
Step 2 evaluate

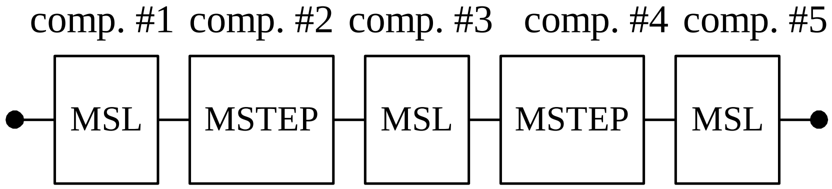
$$\hat{S}_i = \frac{S_i}{\max\limits_{j \in I}\{S_j\}}, i \in I$$

Step 3 put the ith component in Set A if $\hat{S}_i \geq \beta$
otherwise put it in Set B ($\beta = 0.2$)

Coarse Model Decomposition

example: 3:1 microstrip transformer





$\varepsilon_r = 9.7,\ \ H = 25$ mil

$$\boldsymbol{x}_i = [\varepsilon_{ri} \quad H_i]^T, \quad i = 1, \cdots, 5$$

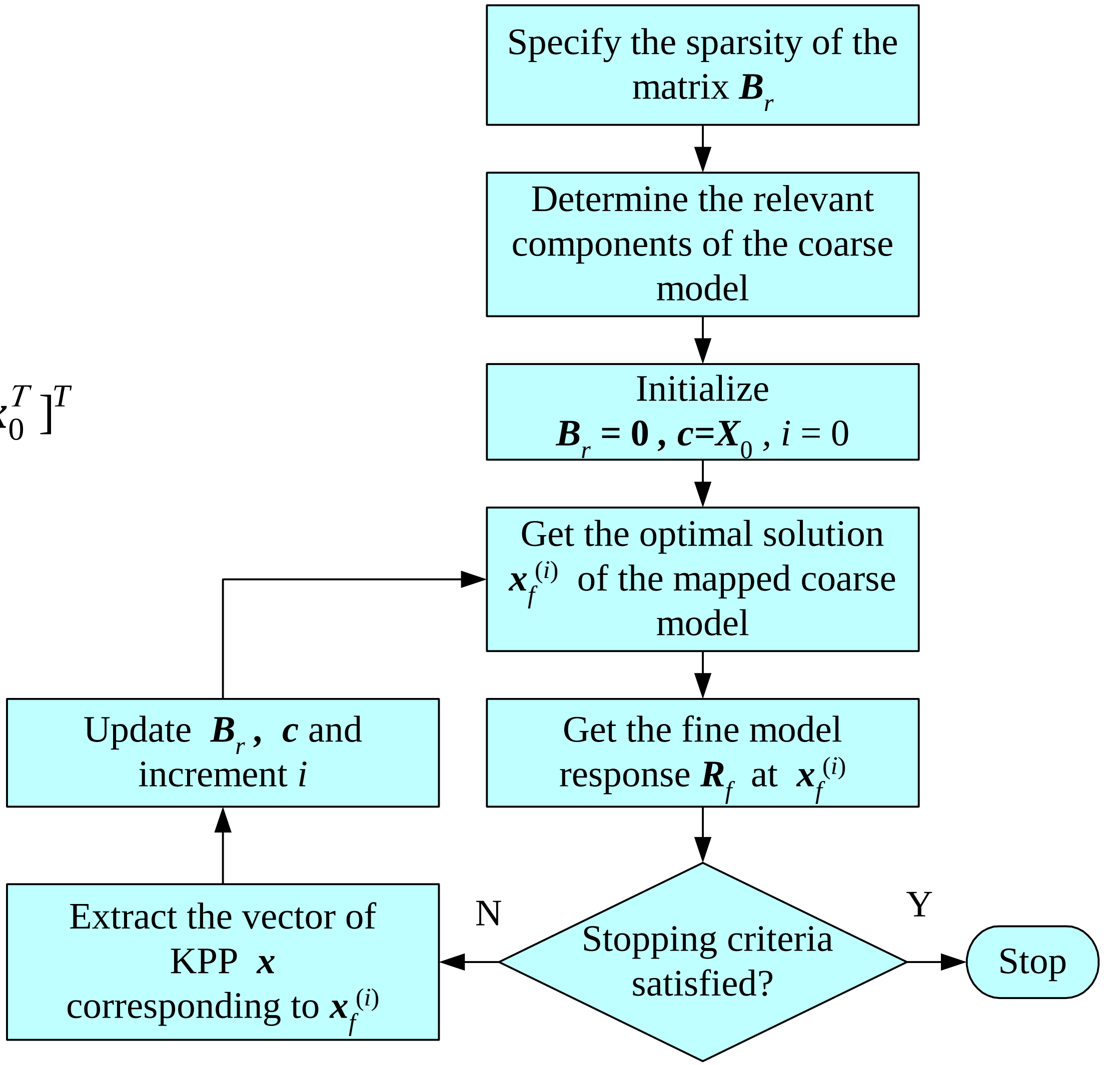
$$S_i = \left\| \left(\frac{\partial \boldsymbol{R}_{\boldsymbol{c}}^{\mathrm{T}}}{\partial \boldsymbol{x}_i} \boldsymbol{D} \right)^{\mathrm{T}} \right\|_F$$

Component #	$\hat{S}_i$
1	1
2	0.05
3	0.39
4	0.04
5	0.77

hence $\boldsymbol{x} = [\boldsymbol{x}_1^T \ \ \boldsymbol{x}_3^T \ \ \boldsymbol{x}_5^T]^T$

ESMDF Algorithm

$$X_0 = [x_0^T \; x_0^T \cdots x_0^T]^T$$



Expanded Space Mapping Optimization Algorithm

mapped coarse model optimization

$$\boldsymbol{x}_f^{(i)} = \arg\min_{\boldsymbol{x}_f} U(\boldsymbol{R}_c(\boldsymbol{x}_f, \boldsymbol{x}))$$

$$\boldsymbol{x} = \boldsymbol{B}_r \ \boldsymbol{x}_r + \boldsymbol{c}$$

$$\boldsymbol{x}_f = [\boldsymbol{x}_r^T \quad \boldsymbol{x}_s^T]^T$$

Expanded Space Mapping Optimization Algorithm

mapped coarse model optimization
exploiting trust region methodology

$$\boldsymbol{h} = \arg\min_{\boldsymbol{h}} U(\boldsymbol{R}_c(\boldsymbol{x}_f^{(i\text{-}1)} + \boldsymbol{h}, \boldsymbol{B}_r \ \boldsymbol{x}_r^{(i\text{-}1)} + \boldsymbol{c}))$$

$$\text{subject to } \|\Lambda \, \boldsymbol{h}\| \leq \delta$$

successful iteration

$$\boldsymbol{x}_f^{(i)} = \begin{cases} \boldsymbol{x}_f^{(i\text{-}1)} + \boldsymbol{h} & \text{if } U(\boldsymbol{R}_f(\boldsymbol{x}_f^{(i\text{-}1)} + \boldsymbol{h})) < U(\boldsymbol{R}_f(\boldsymbol{x}_f^{(i\text{-}1)})) \\ \boldsymbol{x}_f^{(i\text{-}1)} & \text{otherwise} \end{cases}$$

Expanded Space Mapping Optimization Algorithm

KPP extraction

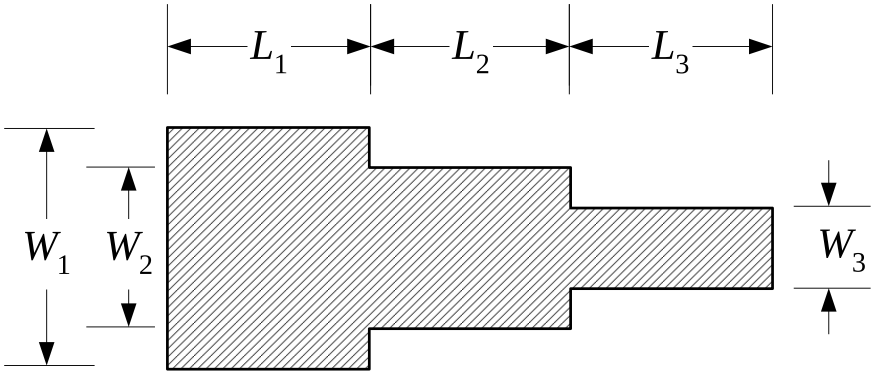
$$\boldsymbol{x}^{(i)} = \arg\min_{\boldsymbol{x}} \left\| \boldsymbol{R}_f(\boldsymbol{x}_f^{(i)}) - \boldsymbol{R}_c(\boldsymbol{x}_f^{(i)}, \boldsymbol{x}) \right\|$$

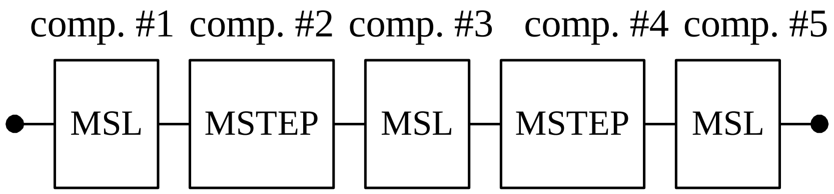
stopping criteria

$$\left\| \boldsymbol{x}_f^{(i)} - \boldsymbol{x}_f^{(i\text{-}1)} \right\| \leq \varepsilon_1$$

$$\left\| \boldsymbol{R}_f(\boldsymbol{x}_f^{(i)}) - \boldsymbol{R}_c(\boldsymbol{x}_f^{(i)}, \boldsymbol{x}^{(i\text{-}1)} + \boldsymbol{B}_r^{(i-1)} \boldsymbol{h}_r^{(i)}) \right\| \leq \varepsilon_2$$

3:1 Microstrip Transformer





load impedance is 50 Ω

source impedance is 150 Ω

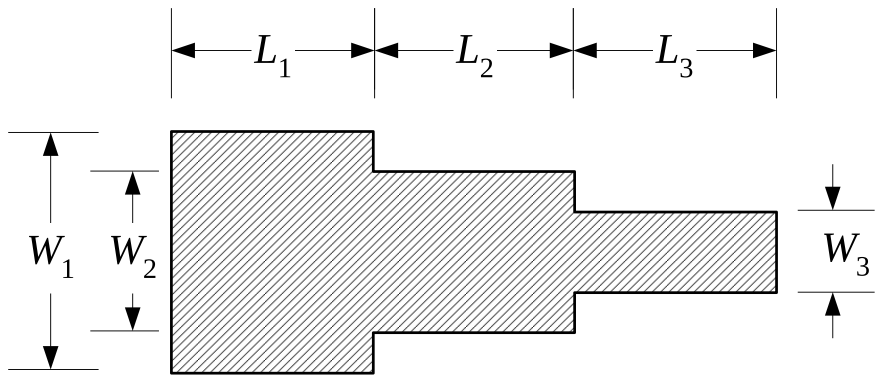
"fine" model: Sonnet's ***em***
parameterized by OSA's Empipe

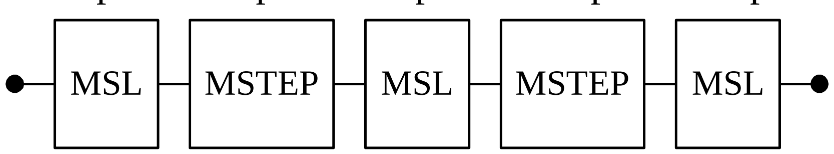
"coarse" model: OSA90/hope

specifications

$|S_{11}| \leq -20$ dB for 5 GHz $\leq \omega \leq$ 15 GHz

3:1 Microstrip Transformer





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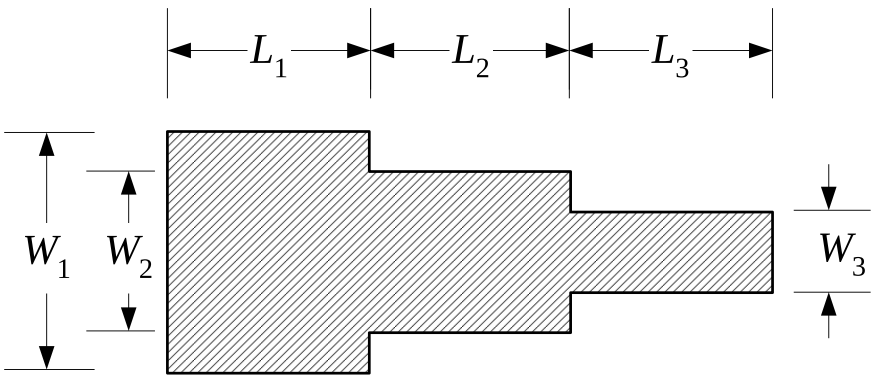

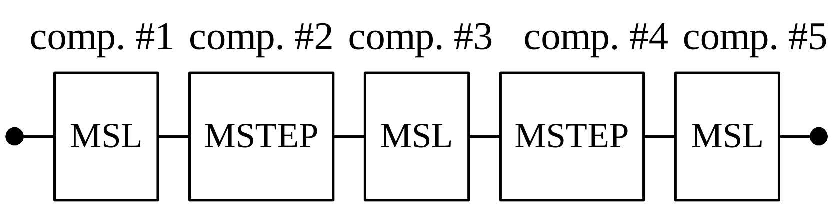

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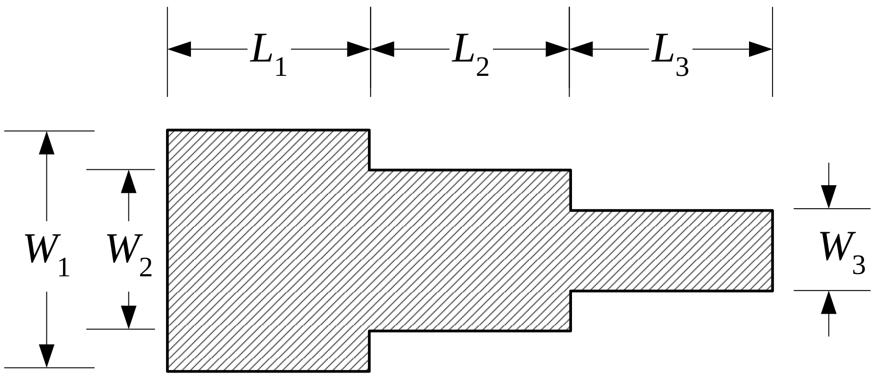

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$$\boldsymbol{x} = [\boldsymbol{x}_1^T \;\; \boldsymbol{x}_3^T \;\; \boldsymbol{x}_5^T]^T \qquad \boldsymbol{x}_i = [\varepsilon_{ri} \quad H_i]^T$$

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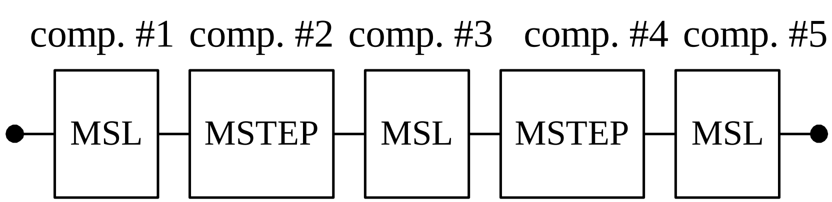
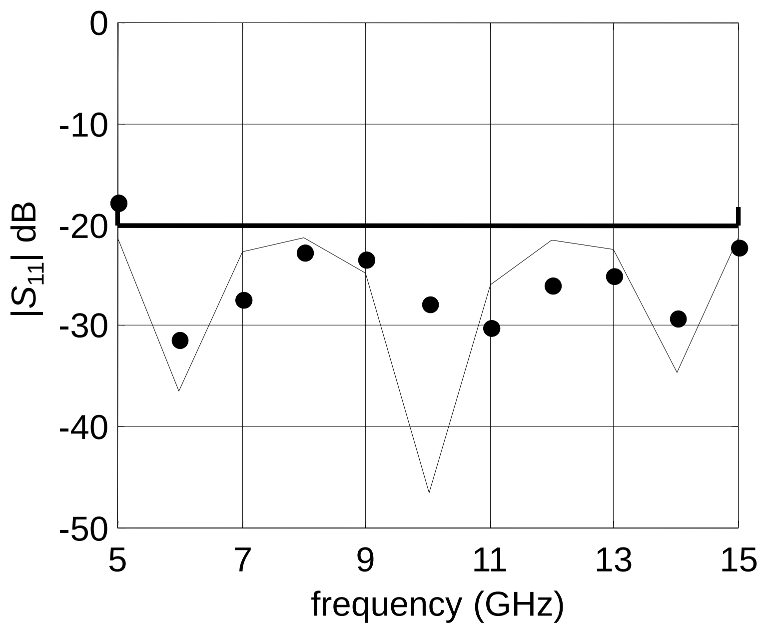
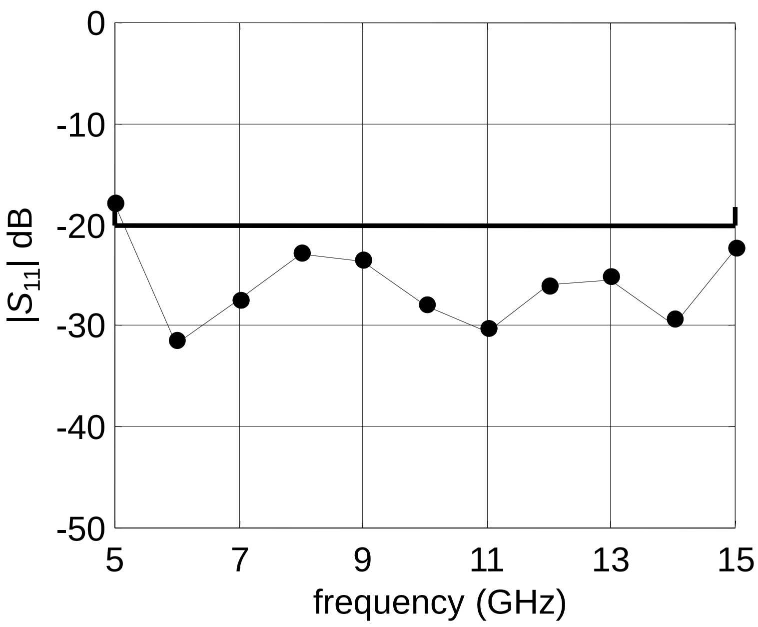


$$\begin{bmatrix} \varepsilon_{r1} \\ H_1 \\ \varepsilon_{r3} \\ H_3 \\ \varepsilon_{r5} \\ H_5 \end{bmatrix} = \boldsymbol{c} + \begin{bmatrix} x & 0 & 0 \\ x & 0 & 0 \\ 0 & x & 0 \\ 0 & x & 0 \\ 0 & 0 & x \\ 0 & 0 & x \end{bmatrix} \begin{bmatrix} W_1 \\ W_2 \\ W_3 \end{bmatrix}$$

3:1 Microstrip Transformer

initial iteration



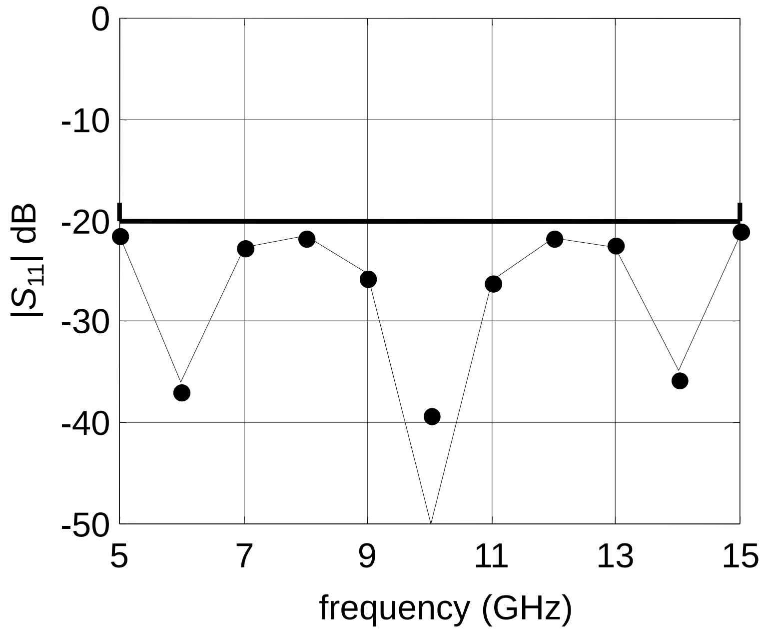


before KPP extraction

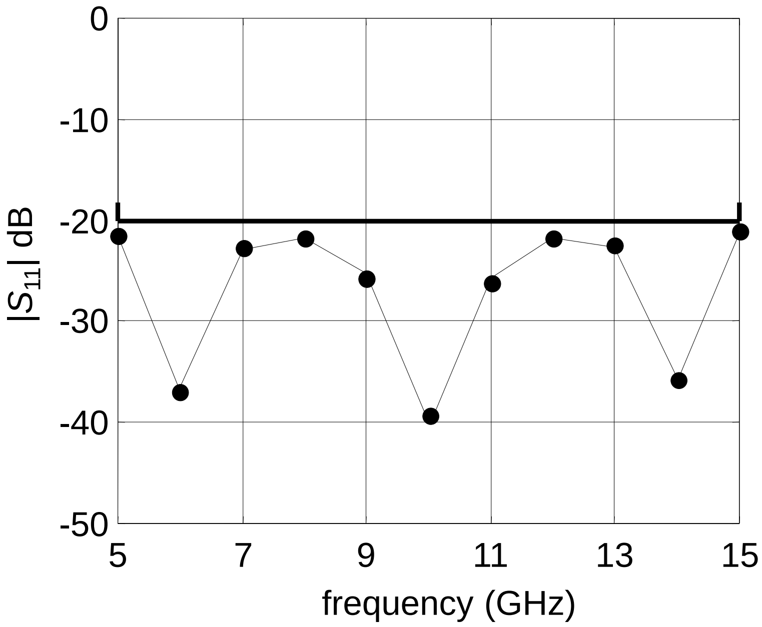
after KPP extraction

3:1 Microstrip Transformer

next iteration



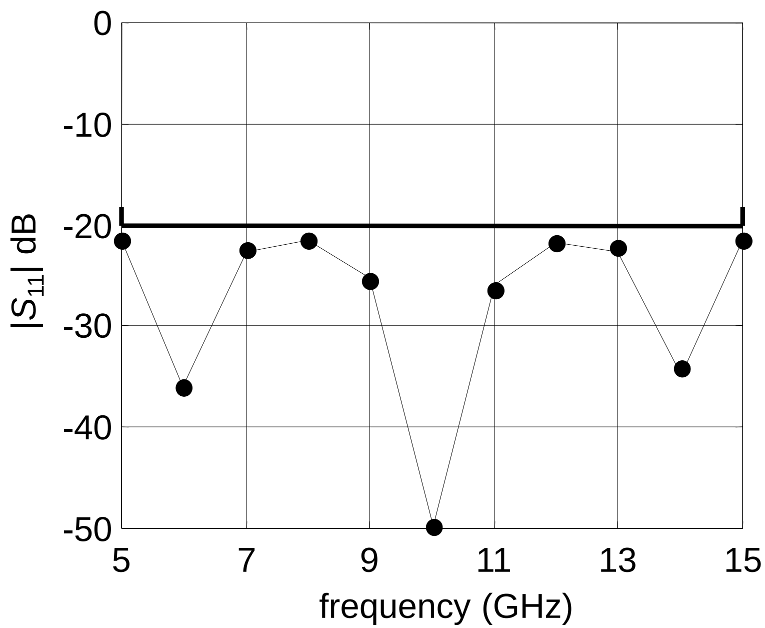
before KPP extraction



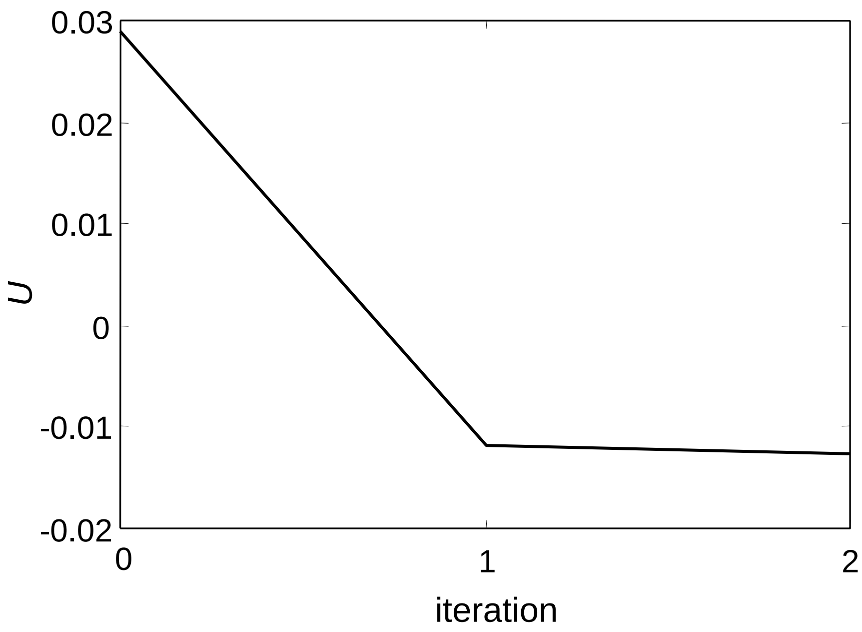
after KPP extraction

3:1 Microstrip Transformer

final iteration



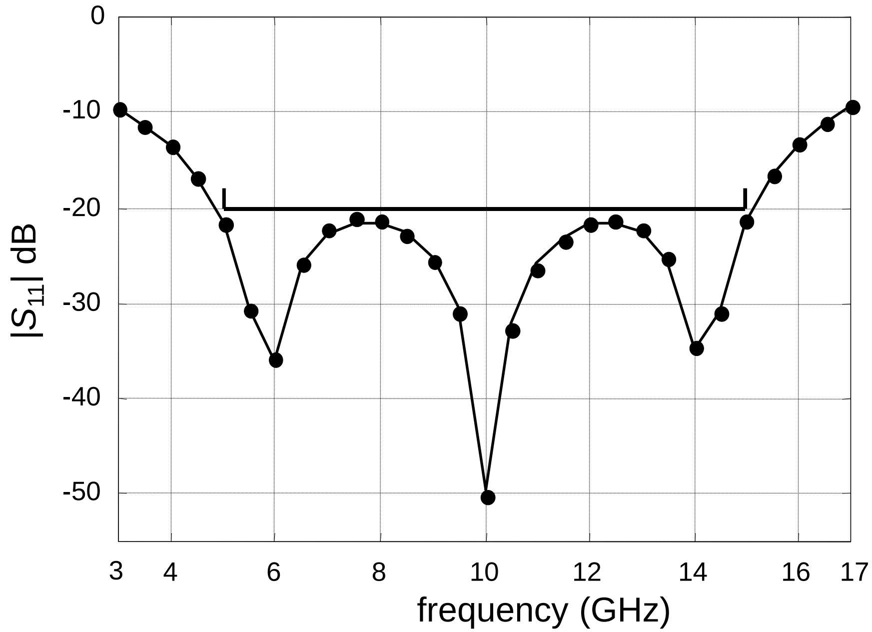
fine model objective function



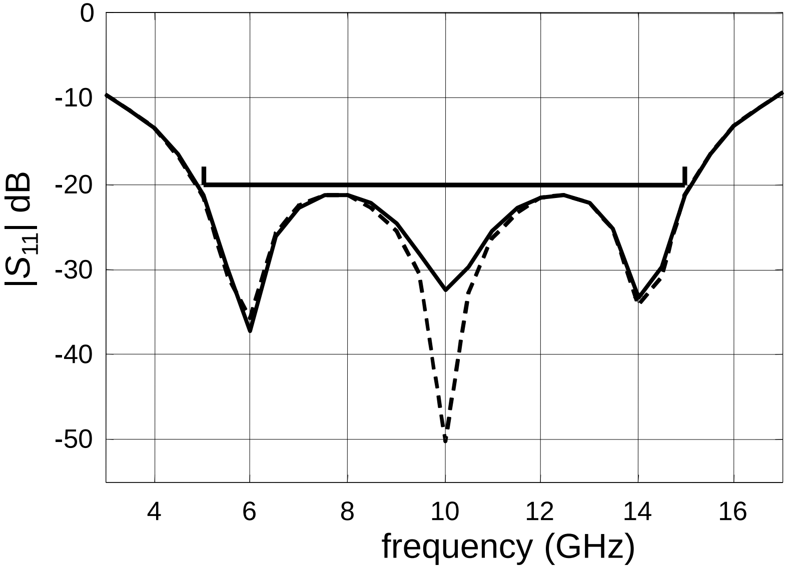
elapsed time by the ESMDF algorithm: 17 min

3:1 Microstrip Transformer

detailed frequency sweep of the optimal response



3:1 Microstrip Transformer Direct EM Optimization



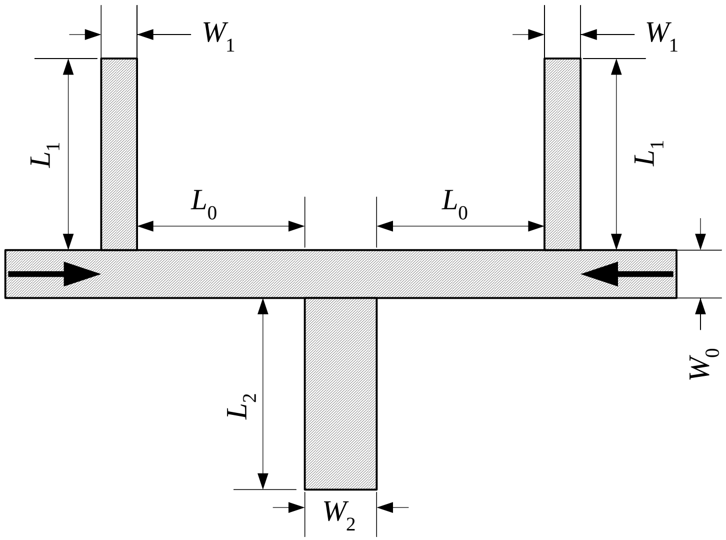
OSA90 optimization

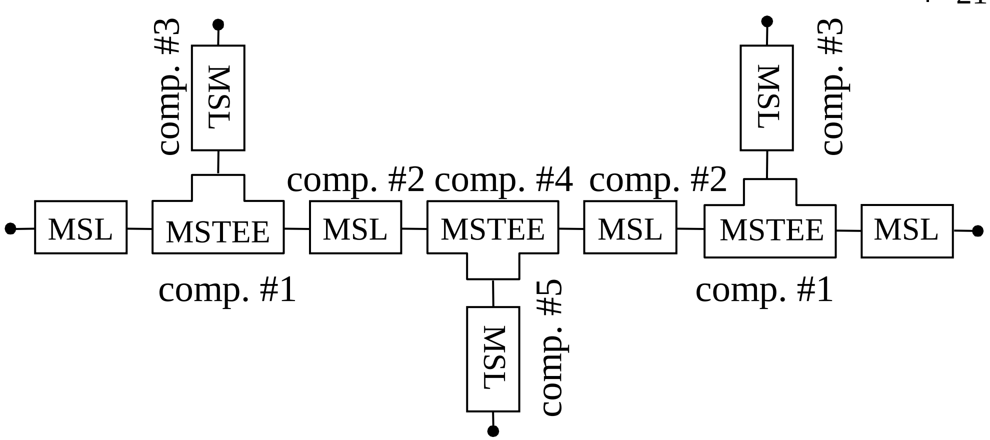
ESMDF algorithm

elapsed time by OSA90 minimax optimization (using quadratic interpolation): 153 min

elapsed time by the ESMDF algorithm: 17 min

Microstrip Bandstop Filter with Open Stubs





"fine" model: Momentum
(Agilent EEsof EDA)

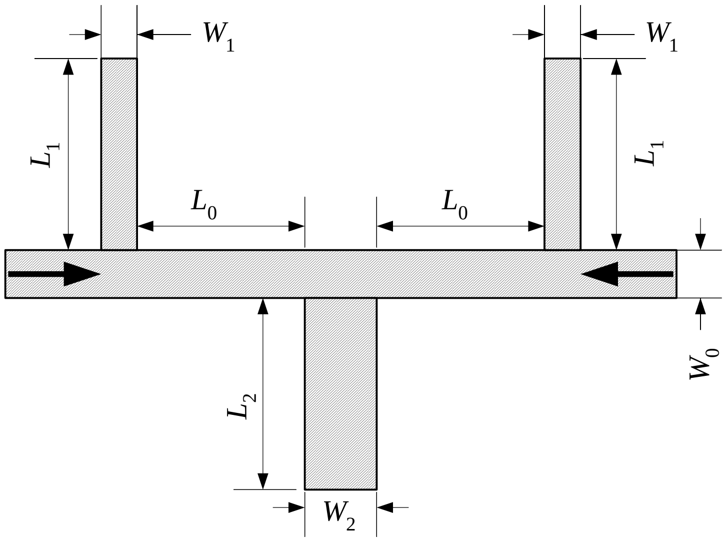
"coarse" model: OSA90/hope

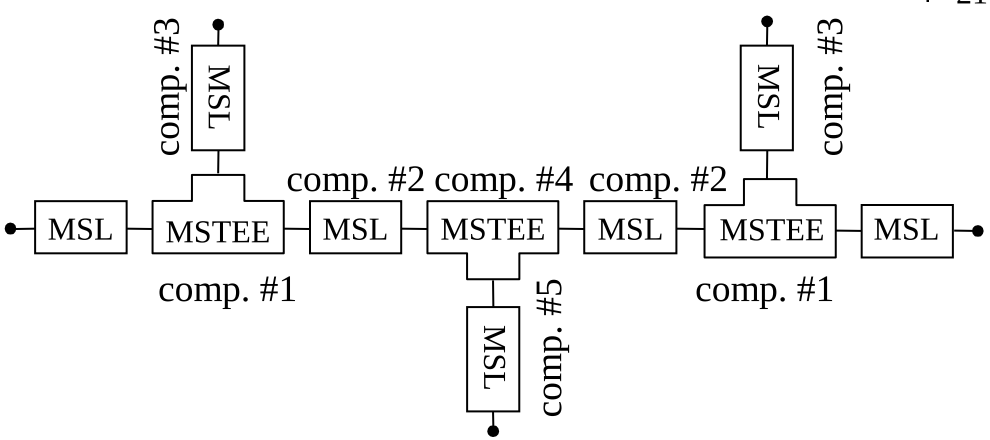
specifications

$|S_{21}| \geq$ -1 dB for $\omega \geq$ 12 GHz and $\omega \leq$ 8 GHz

$|S_{21}| \leq$ -25 dB for 9 GHz $\leq \omega \leq$ 11 GHz

Microstrip Bandstop Filter with Open Stubs





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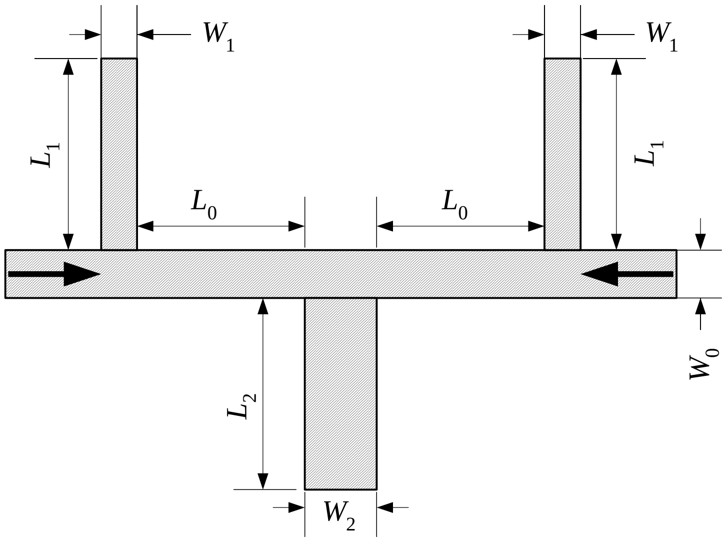

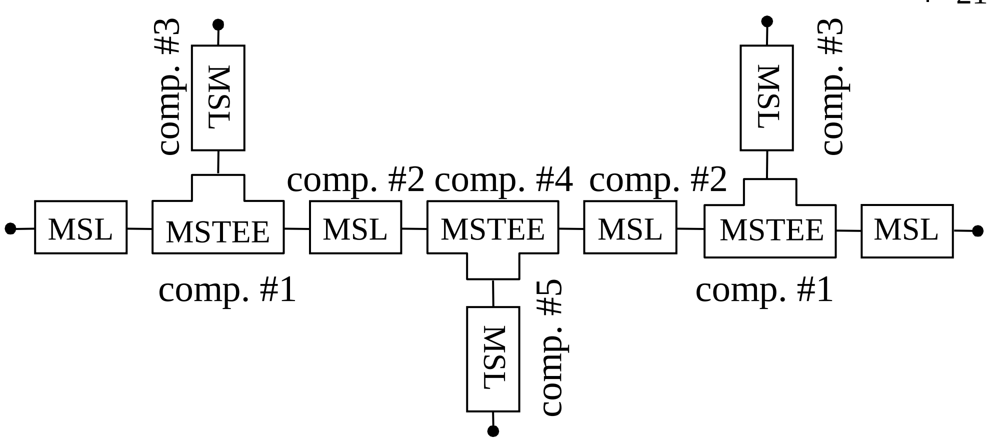

“fine” model: Momentum *(Agilent EEsof EDA)*

Agilent

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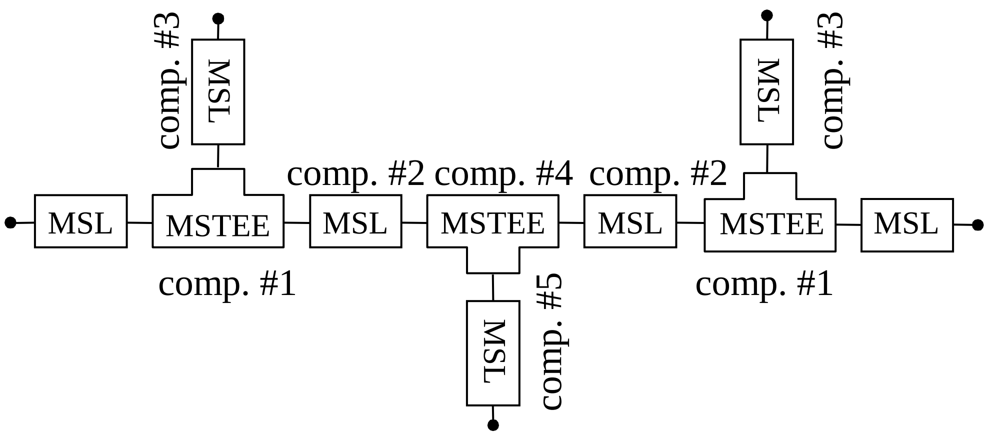
Microstrip Bandstop Filter with Open Stubs

coarse model decomposition



$$S_i = \left\| \left(\frac{\partial \boldsymbol{R}_c^{\mathrm{T}}}{\partial \boldsymbol{x}_i} \boldsymbol{D} \right)^{\mathrm{T}} \right\|_F$$

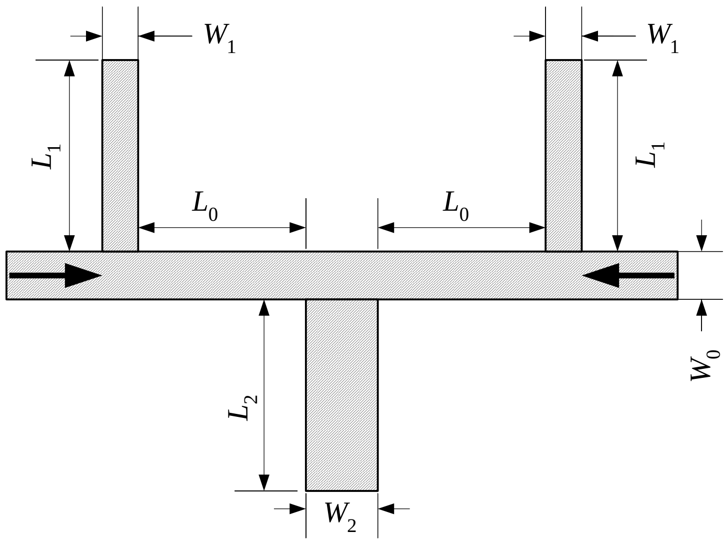
Component #	$\hat{S}_i$
1	0.1420
2	0.6359
3	0.8395
4	0.1858
5	1.0000

$\varepsilon_r = 9.4$, $H = 25$ mil

$$\boldsymbol{x}_i = [\varepsilon_{ri} \quad H_i]^T, \quad i = 1, \cdots, 5$$

hence $\boldsymbol{x} = [\boldsymbol{x}_2^T \ \boldsymbol{x}_3^T \ \boldsymbol{x}_5^T]^T$

Microstrip Bandstop Filter with Open Stubs



$$\boldsymbol{x}_f = [W_1 \quad W_2 \quad L_0 \quad L_1 \quad L_2]^T$$

$$\boldsymbol{x}_r = [W_1 \quad W_2]^T$$

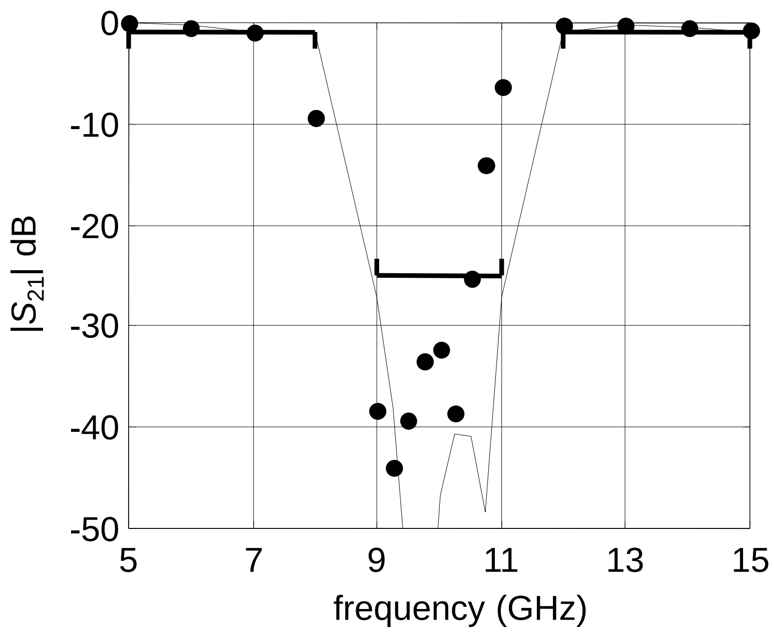
$$\boldsymbol{x} = [\boldsymbol{x}_2^T \ \boldsymbol{x}_3^T \ \boldsymbol{x}_5^T]^T \quad \boldsymbol{x}_i = [\varepsilon_{ri} \quad H_i]^T$$

$$\boldsymbol{x} = \boldsymbol{c} + \boldsymbol{B}_r \ \boldsymbol{x}_r$$

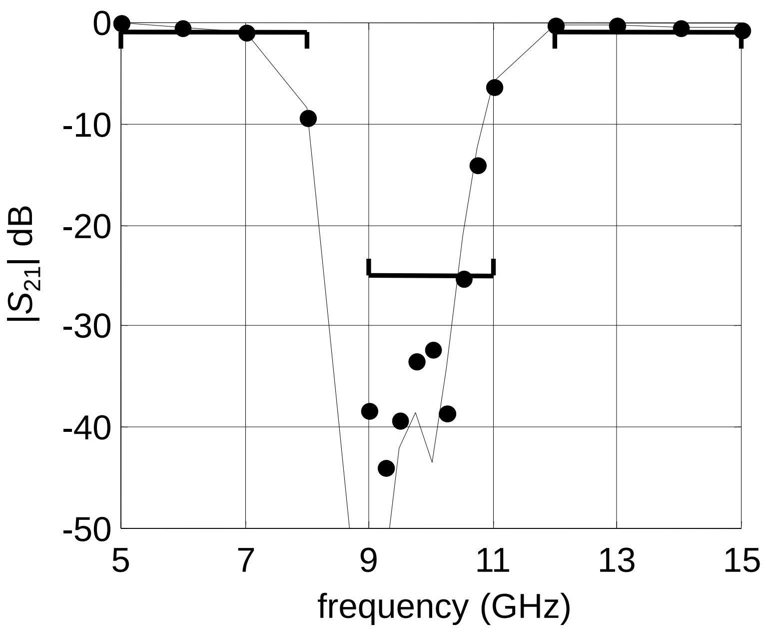
$$\begin{bmatrix} \varepsilon_{r2} \\ H_2 \\ \varepsilon_{r3} \\ H_3 \\ \varepsilon_{r5} \\ H_5 \end{bmatrix} = \boldsymbol{c} + \begin{bmatrix} 0 & 0 \\ 0 & 0 \\ \text{x} & 0 \\ \text{x} & 0 \\ 0 & \text{x} \\ 0 & \text{x} \end{bmatrix} \begin{bmatrix} W_1 \\ W_2 \end{bmatrix}$$

Microstrip Bandstop Filter with Open Stubs

initial response



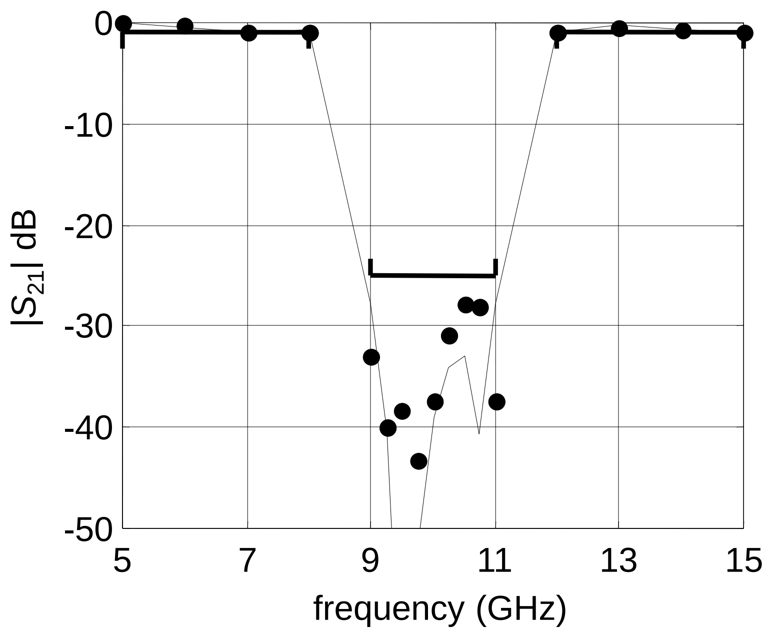
before KPP extraction



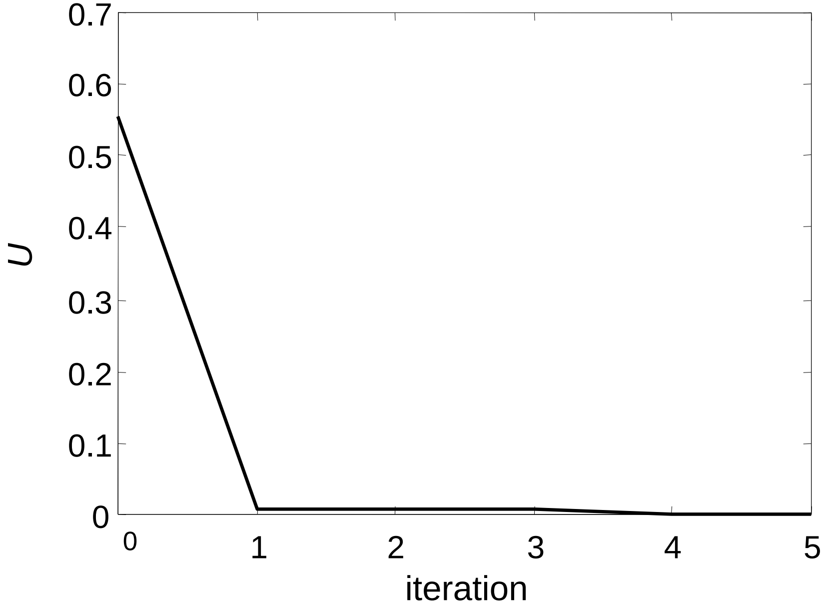
after KPP extraction

Microstrip Bandstop Filter with Open Stubs

final response



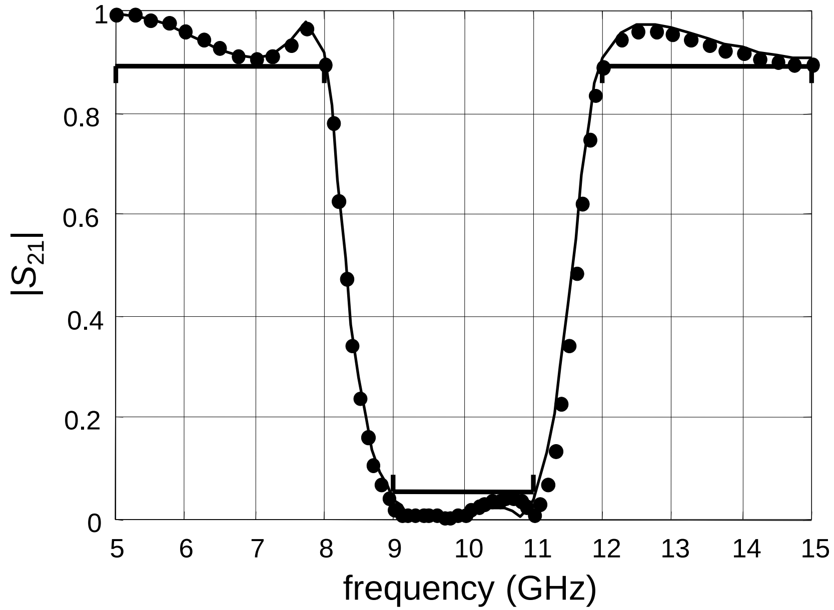
fine model objective function

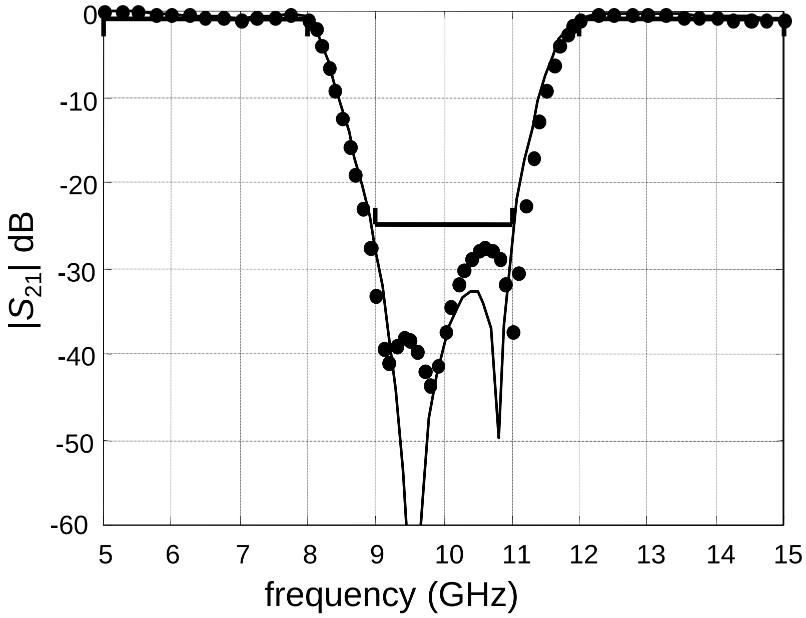


elapsed time by the ESMDF algorithm: 1.5 hr

Microstrip Bandstop Filter with Open Stubs

detailed frequency sweep at the optimal solution





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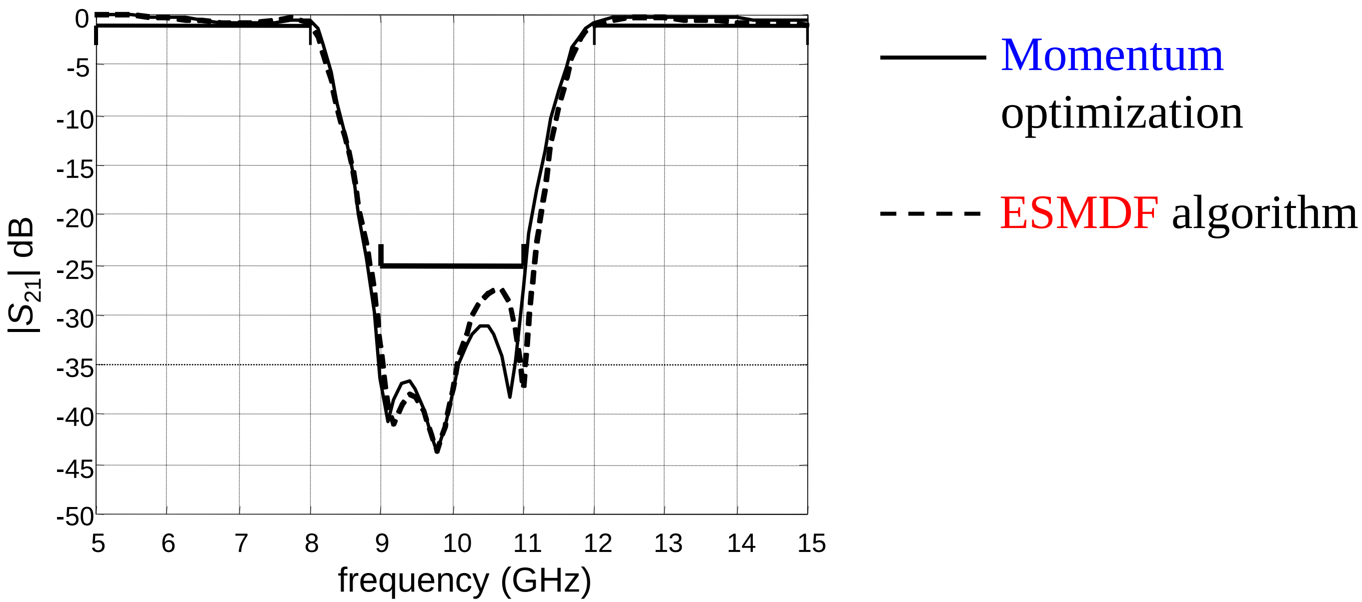
direct optimization



elapsed time by Momentum optimization (using quadratic interpolation): 10 hr

elapsed time by the ESMDF algorithm: 1.5 hr

Conclusions

we expand the original space mapping approach

we exploit key preassigned parameters (KPP)

we tune the KPP in “relevant components” of the coarse model
to align it with the fine model

a mapping is established from the optimization variables to the KPP

the mapping is updated iteratively

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3:1 Microstrip Transformer Yield Analysis

utilize the mapped coarse model obtained at the final iteration

assume a uniform distribution with 0.25 mil tolerance on all six geometrical parameters

estimate the yield at the solution obtained by the ESMDF algorithm

mapped coarse model: 78 %

fine model: 79%

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