Space Mapping: From Practical Engineering Modeling to Highly Optimized Designs Exploiting Surrogates

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Space Mapping: From Practical Engineering Modeling to Highly Optimized Designs Exploiting Surrogates

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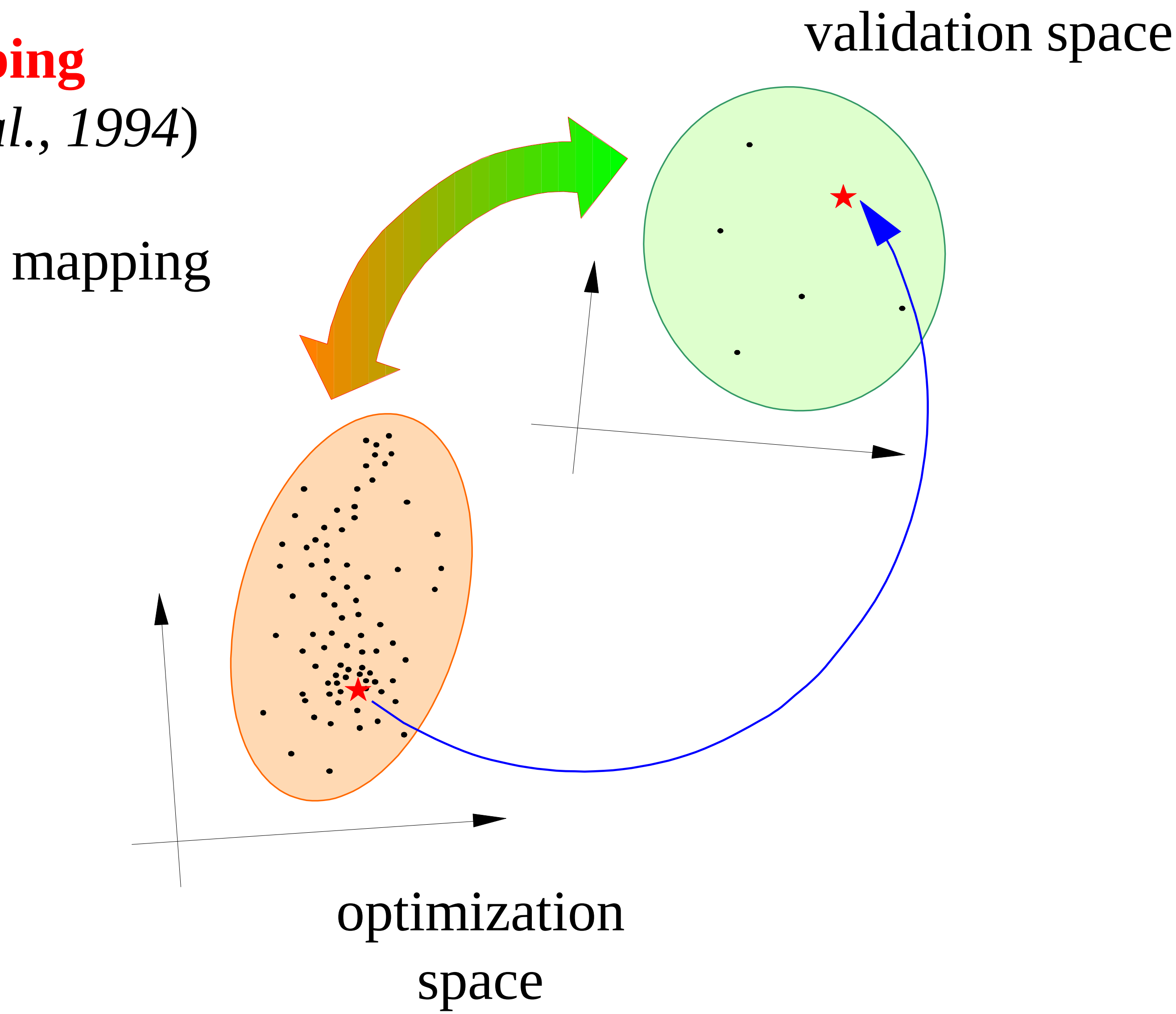
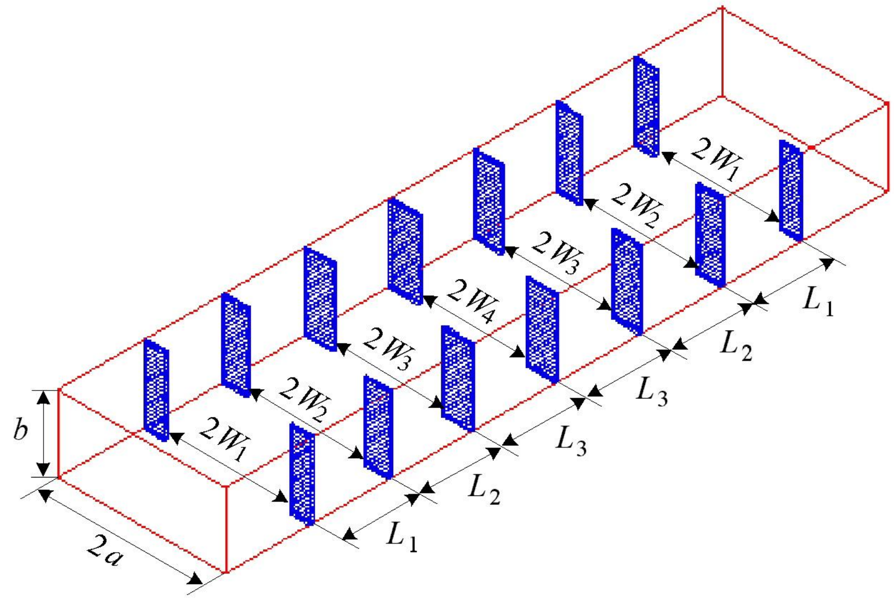
Space Mapping

(*Bandler et al., 1994*)

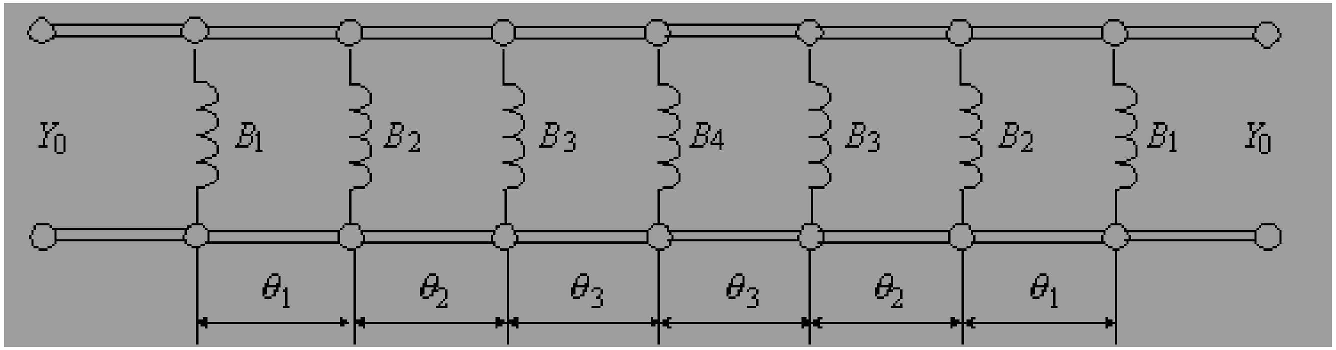


H-plane Waveguide Filter Design (*Young et. al., 1963, Bakr et al., 1999*)

H-plane filter



circuit model (*Marcuvitz,1951*)

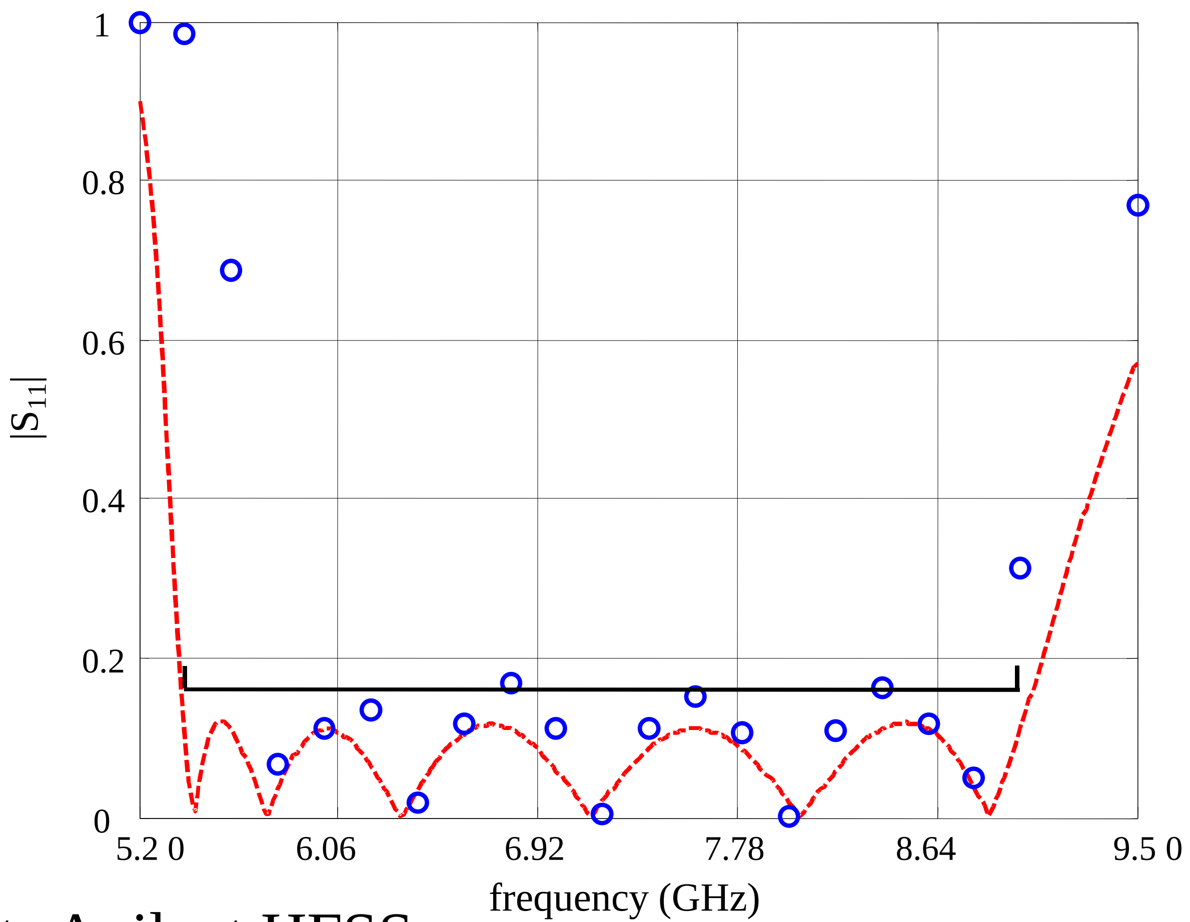


H-plane Waveguide Filter Space Mapping Design

(*Bandler et al., 2004*)

optimal coarse model response (---)

initial fine model* response (○)



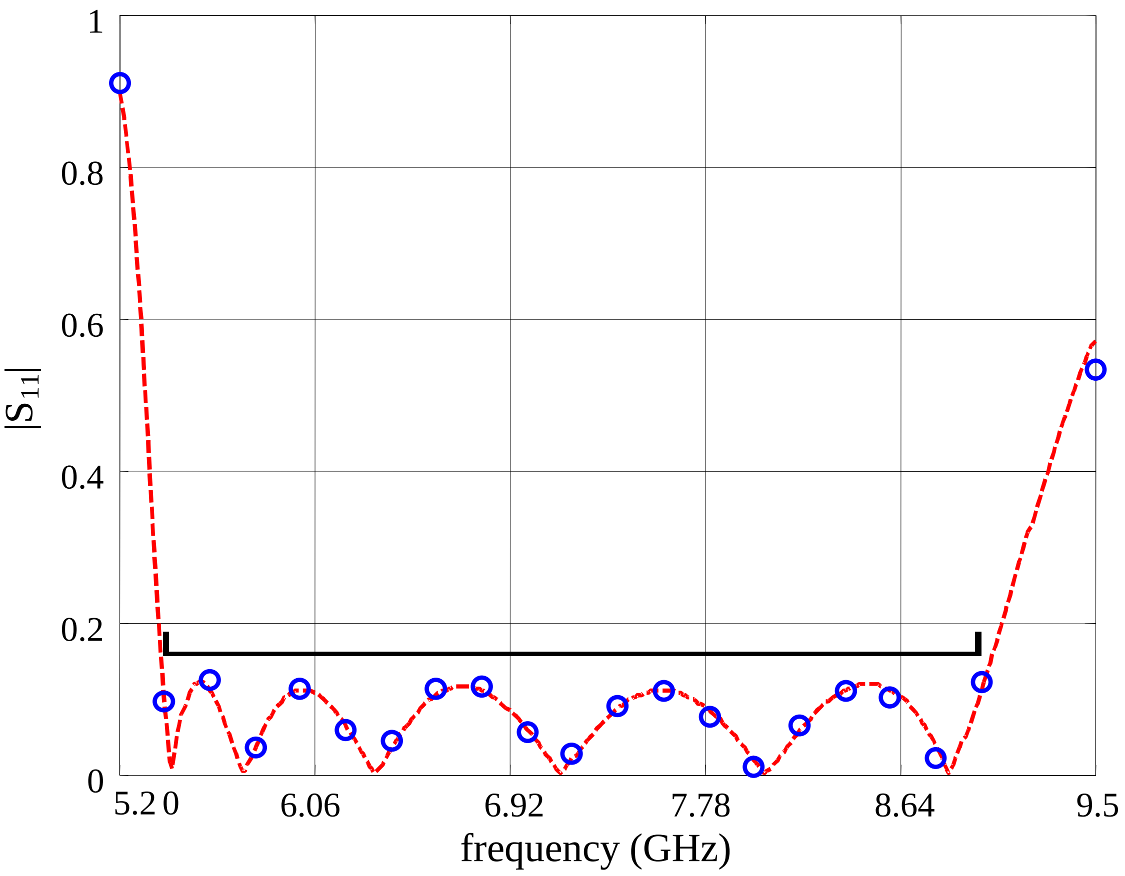
*the fine model exploits Agilent HFSS

H-plane Waveguide Filter Space Mapping Design

(*Bandler et al., 2004*)

optimal coarse model response (---)

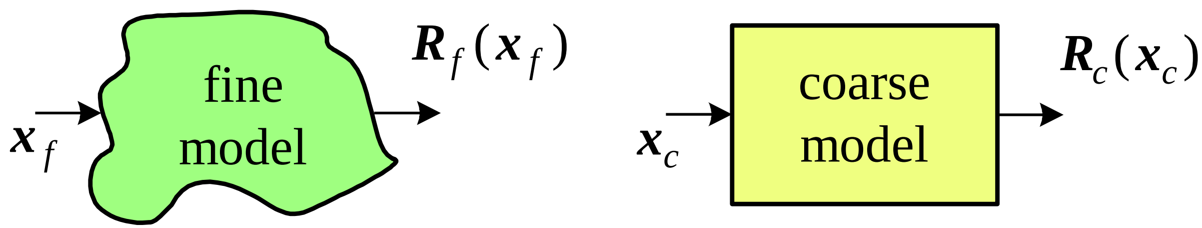
fine model* (○)
SMIS algorithm,
3 iterations,
4 frequency sweeps
(excluding Jacobian estimations)

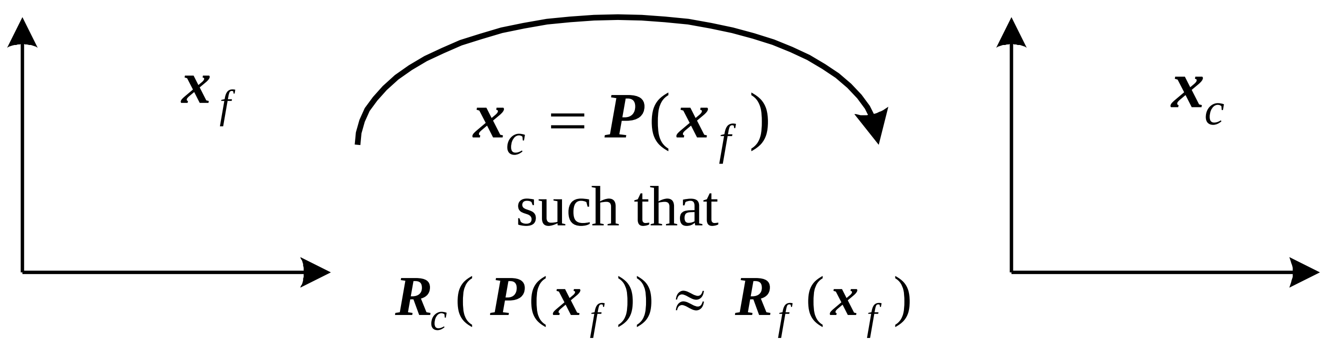


*the fine model exploits Agilent HFSS

The Space Mapping Concept

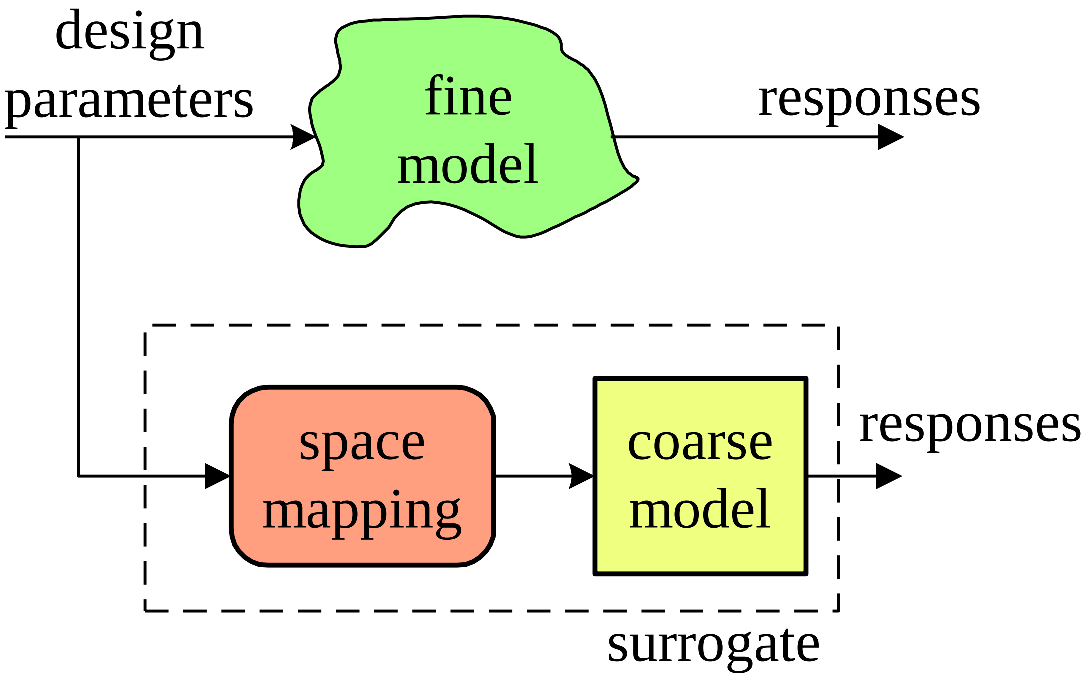
(Bandler et al., 1994-)





Explicit Space Mapping Concept

(*Bandler et al., 1994-*)



used in the microwave industry (e.g., Com Dev, 2003-2004, for optimization of dielectric resonator filters and multiplexers)

Aggressive Space Mapping Practice—Cheese Cutting Problem

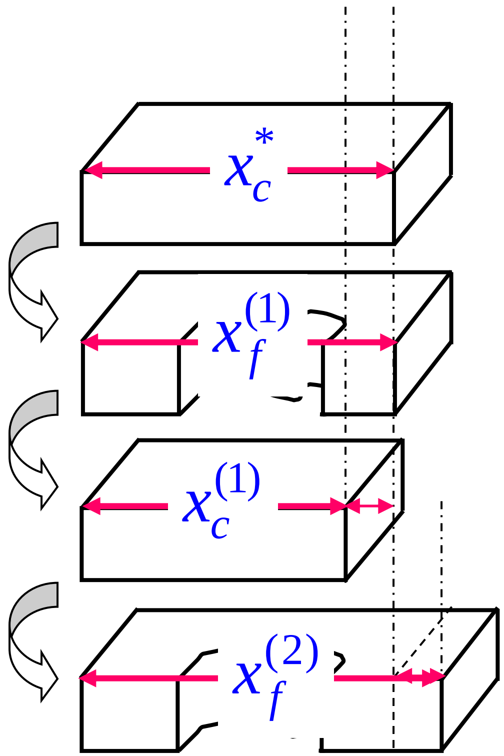
(*Bandler et al., 2002*)

optimal coarse model

initial guess

PE

prediction



$$x_f^{(1)} = x_c^*$$

$$x_f^{(2)} = x_f^{(1)} + P^{-1}(x_c^* - x_c^{(1)})$$

$$x_f^{(2)} = x_f^{(1)} + x_c^* - x_c^{(1)}$$

the “coarse” model is obviously idealized

Space Mapping: a Glossary of Terms

Space Mapping	transformation, link, adjustment, correction, shift (in parameters or responses)
Coarse Model	simplification or convenient representation, companion to the fine model, auxiliary representation, cheap model idealized model, physically expressive, low fidelity
Fine Model	accurate representation of system considered, device under test, component to be optimized, expensive model, high fidelity

Space Mapping: a Glossary of Terms

Surrogate	model, approximation or representation to be used, or to act, in place of, or as a substitute for, the system under consideration
Updated Surrogate	mapped or enhanced coarse model corrected coarse model
Surrogate Model	alternative expression for Surrogate
Target Response	response the fine model should achieve, (usually) optimal response of an idealized "coarse" model, an enhanced coarse model, or surrogate

Space Mapping: a Glossary of Terms

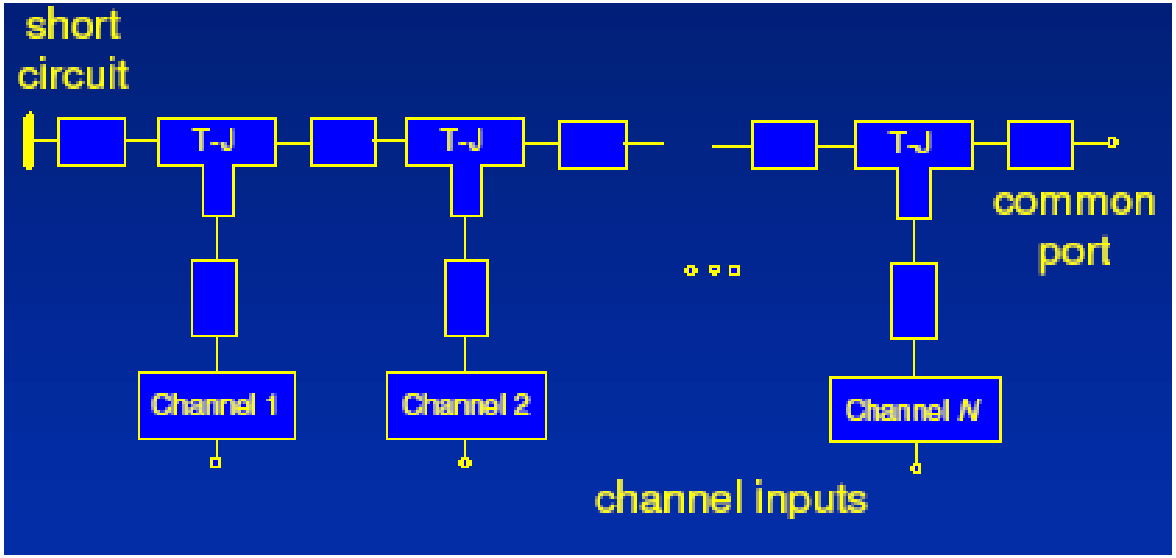
(Parameter/input) Space Mapping[1]	mapping, transformation or correction of design variables
(Response) Output Space Mapping[2]	mapping, transformation or correction of responses
Response Surface Approximation	linear/quadratic/polynomial approximation of responses w.r.t. design variables

[1]concept used by Giunta *et al.* (May 16)
[2]Natalia Alexandrov's "high-order model management" (May 16)

Space Mapping Design of Dielectric Resonator Multiplexers

(*Ismail et al., 2003, Com Dev, Canada*)

manifold multiplexer: coarse channel model (equivalent circuit)
fine channel model (HFSS + circuit theory)

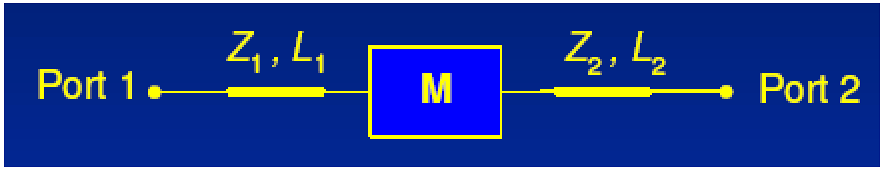


20 manifold parameters

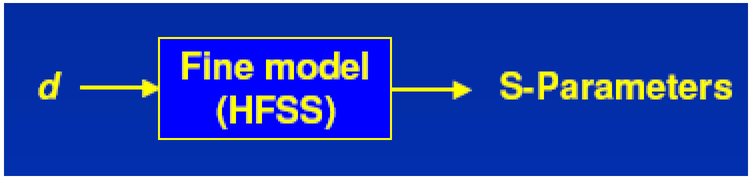
Space Mapping Design of Dielectric Resonator Multiplexers

(*Ismail et al., 2003, Com Dev, Canada*)

channel coarse model (ideal equivalent circuit)



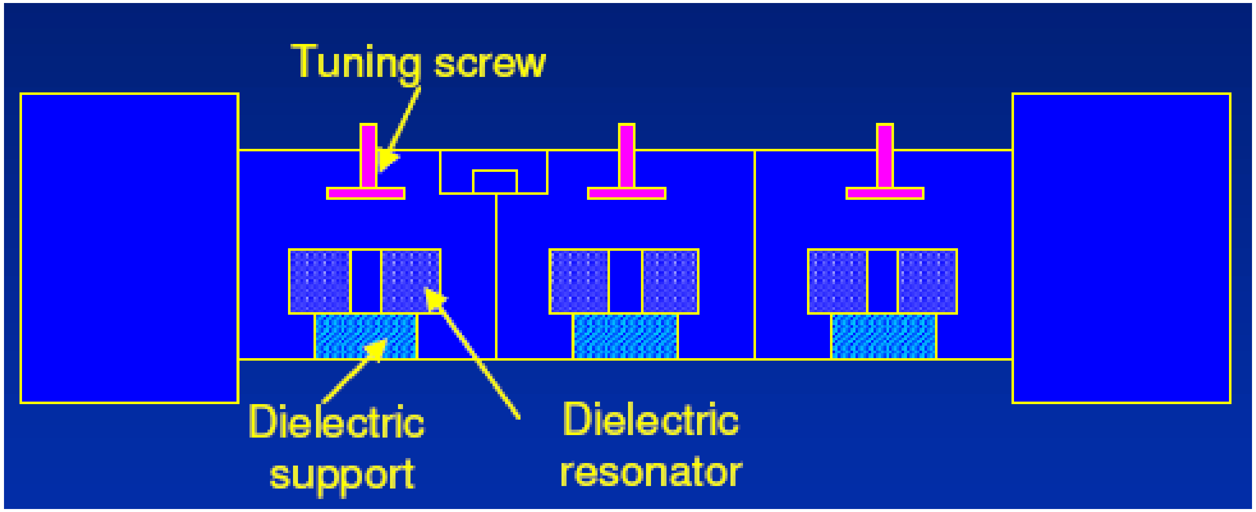
channel fine model (HFSS finite element)



Space Mapping Design of Dielectric Resonator Multiplexers

(*Ismail et al., 2003, Com Dev, Canada*)

5-pole dielectric resonator filter



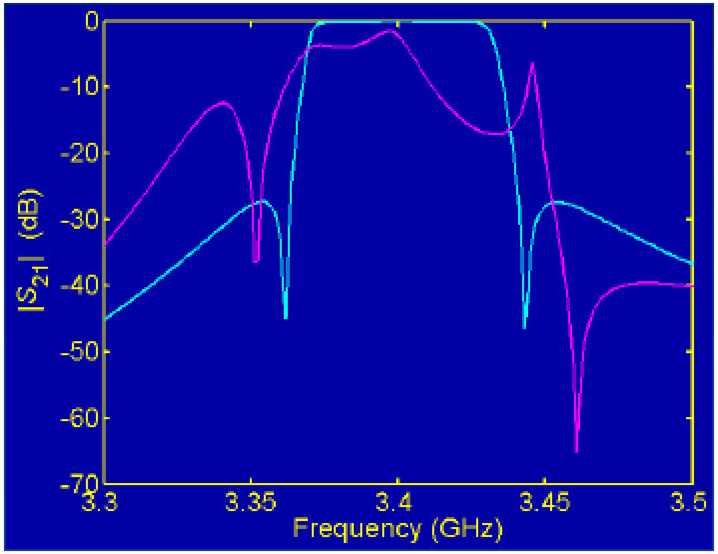
tuning screws are included in the HFSS analysis

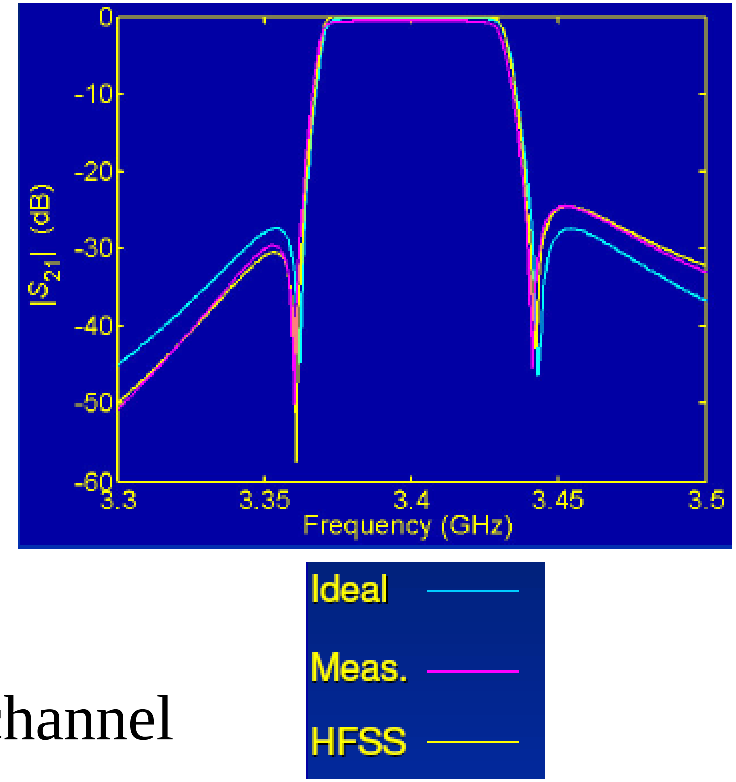
Space Mapping Design of Dielectric Resonator Multiplexers

(*Ismail et al., 2003, Com Dev, Canada*)

initial response

final response (10 iterations)



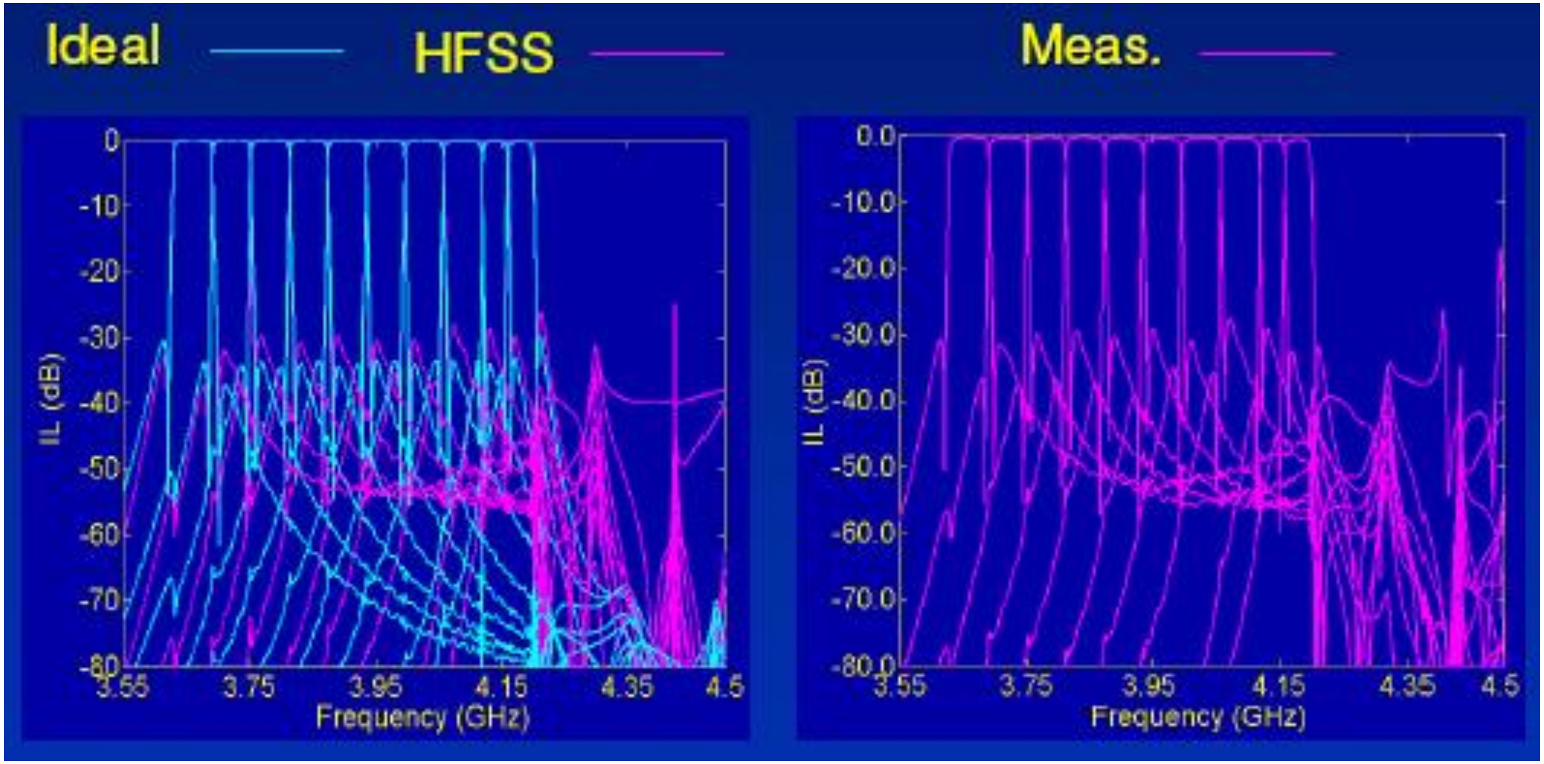


TRASM (1998) is applied to each channel

Space Mapping Design of Dielectric Resonator Multiplexers

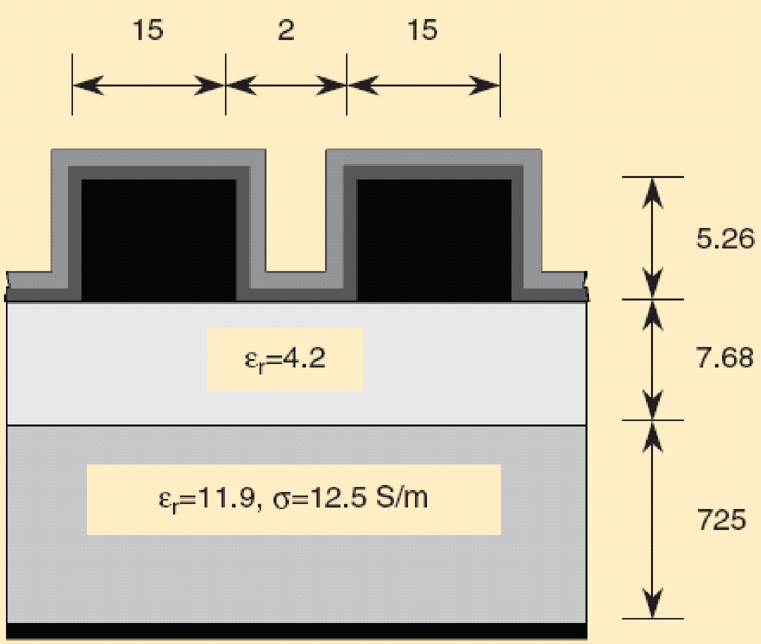
(*Ismail et al., 2003, Com Dev, Canada*)

10-channel output multiplexer, 140 variables

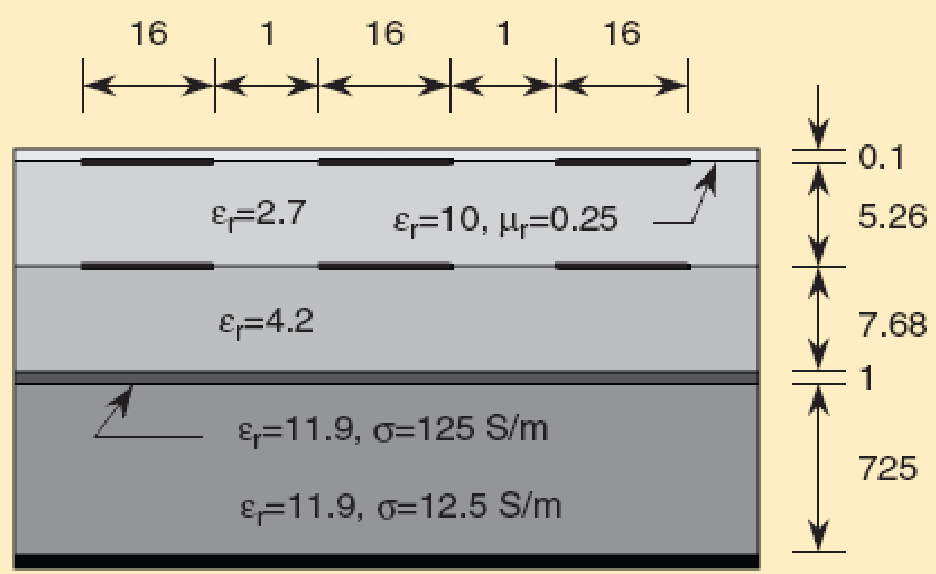


Implicit Space Mapping Design of Thick, Tightly Coupled Conductors (*Rautio, 2004, Sonnet*)

thick, closely spaced conductors
on silicon (fine model)



“space-mapping” (top) layer
(coarse model)



Space Mapping Crashworthiness Design of Saab 9^3

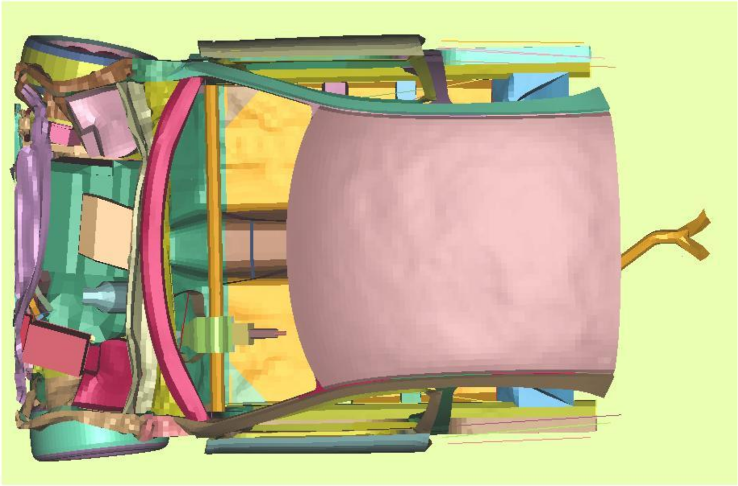
(*Redhe et al., 2001-2004, Sweden*)

[type “saab space mapping” into Google]

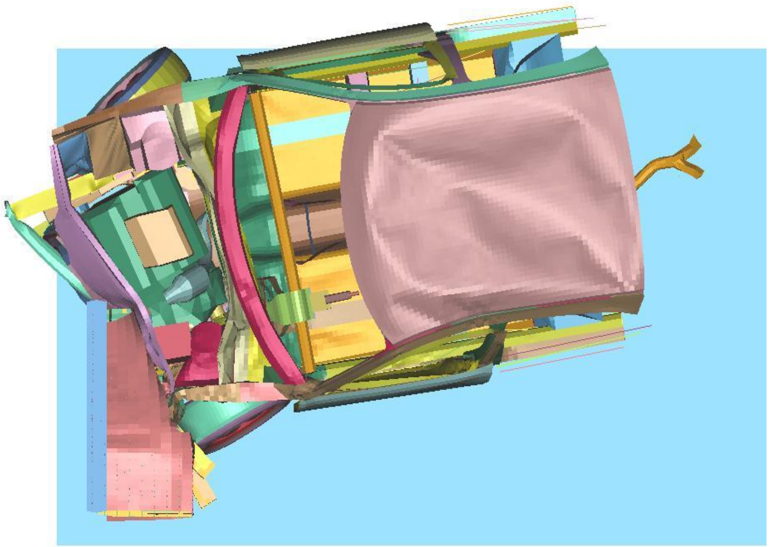
In crashworthiness finite element simulations, each evaluation is expensive. Space Mapping reduces the total computing time to optimize the vehicle structure more than 50% compared to traditional optimization.

Space Mapping has been applied to the complete FE model of the new Saab 9^3 Sport Sedan. Intrusion into the passenger compartment area after the impact was reduced by 32% with no reduction in other crashworthiness responses.

Space Mapping Crashworthiness Design of Saab 9^3 Frontal Impact (*Nilsson and Redhe, 2005, Sweden*)

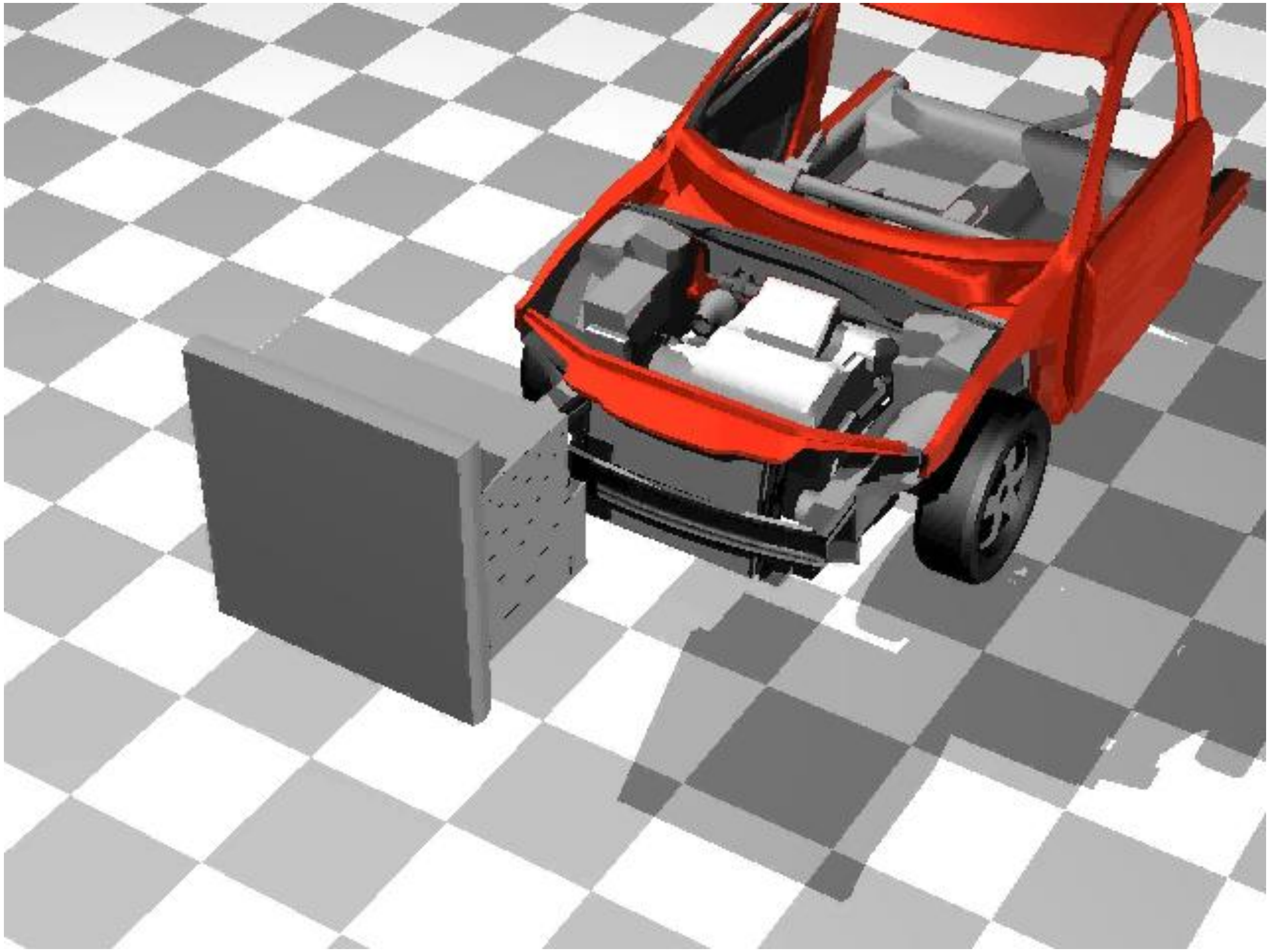


US-NCAP



EU-NCAP

Space Mapping Crashworthiness Design of Saab 9[3] Frontal Impact (*Nilsson and Redhe, 2005, Sweden*)



Space Mapping Crashworthiness Design of Saab 9^3

(*www.studyinsweden.se, 2005*)

Space Mapping cuts calculation times by three fourths compared with traditional RSM optimization methods

driven straight into a steel barrier at 56 km/h

penetration of the passenger space by the material was reduced by 32 percent

Space Mapping Crashworthiness Design of Saab 9[5]

(*Redhe et al., 2005*)

structural optimization problem

a complete FE vehicle model,
consisting of 350,000 shell elements
and a computing time of 100 hours

intrusion into the passenger
compartment area was reduced by 16%

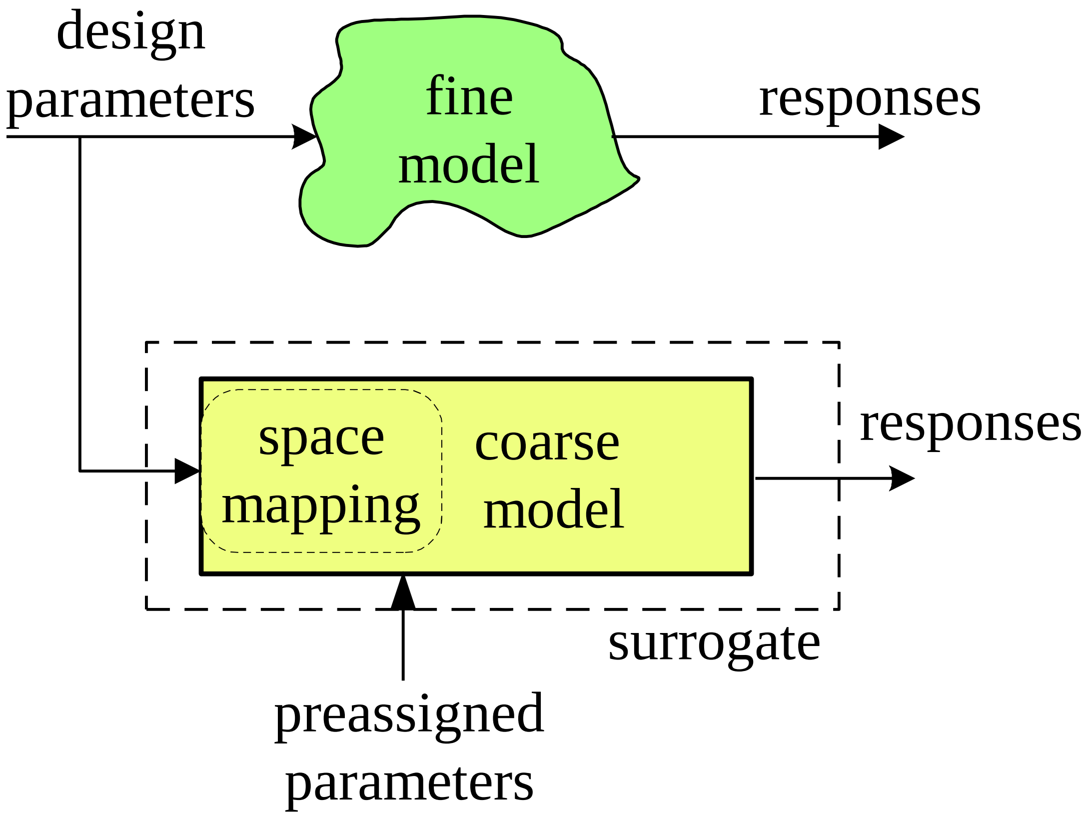
computing time reduced by 57% relative to traditional
RSM optimization

Space Mapping Implementation and Applications 2005

SIAM Conf. on Optimization, Stockholm, Sweden, May 15-19, 2005;
Space Mapping: A Knowledge Based Engineering Modeling and Optimization Methodology Exploiting Surrogates (*Bandler and Madsen*, *Organizers*)

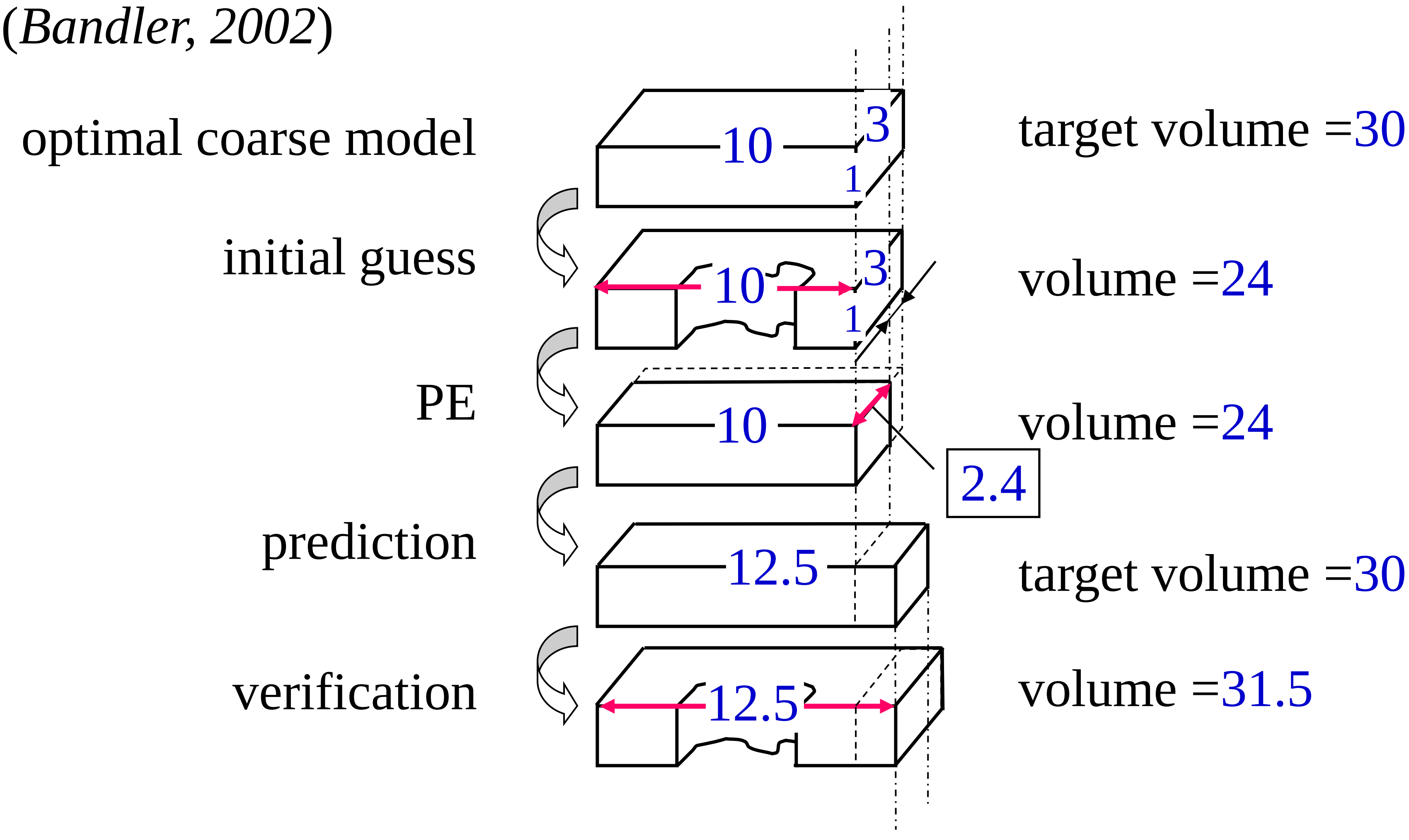
K. Madsen, "Introduction to Space Mapping"
S. Koziel, "On the Convergence of Space Mapping Optimization Algorithms"
J.W. Bandler, "Optimal Design of High-Fidelity Engineering Device Models Through Space Mapping"
L. Nielsson, "Optimization using Space Mapping, with Application on Contact and Impact Mechanical Problems"
Q.J. Zhang, "Neuro-Space Mapping for Nonlinear Electronic Device Modeling"
F. Pedersen, "Modeling Thermally Active Building Components Using Space Mapping"
D. Echeverria, "Multi-Level Optimization with the Space-Mapping Technique"
D. Lahaye, "Space-Mapping Applied to Linear Actuator Design"

Implicit Space Mapping Concept
(*Bandler et al., 2004*)



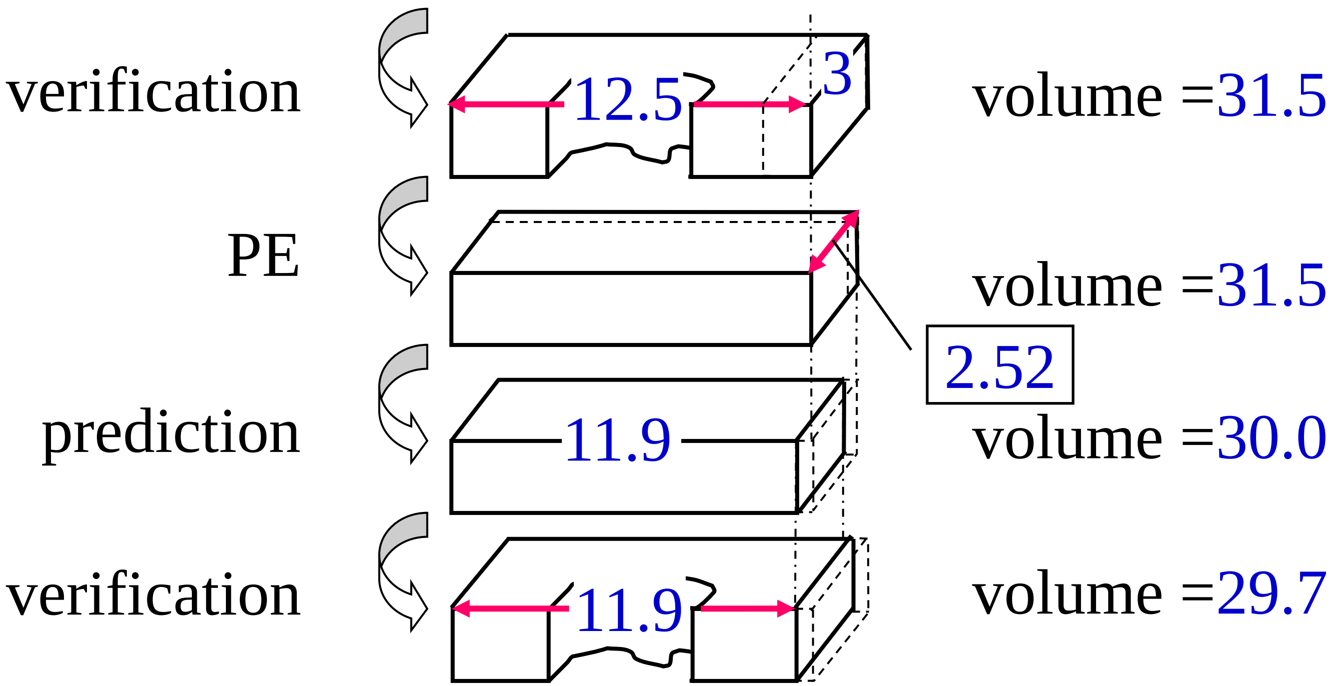
Implicit Space Mapping Practice—Cheese Cutting Problem

(*Bandler, 2002*)



Implicit Space Mapping Practice—Cheese Cutting Problem

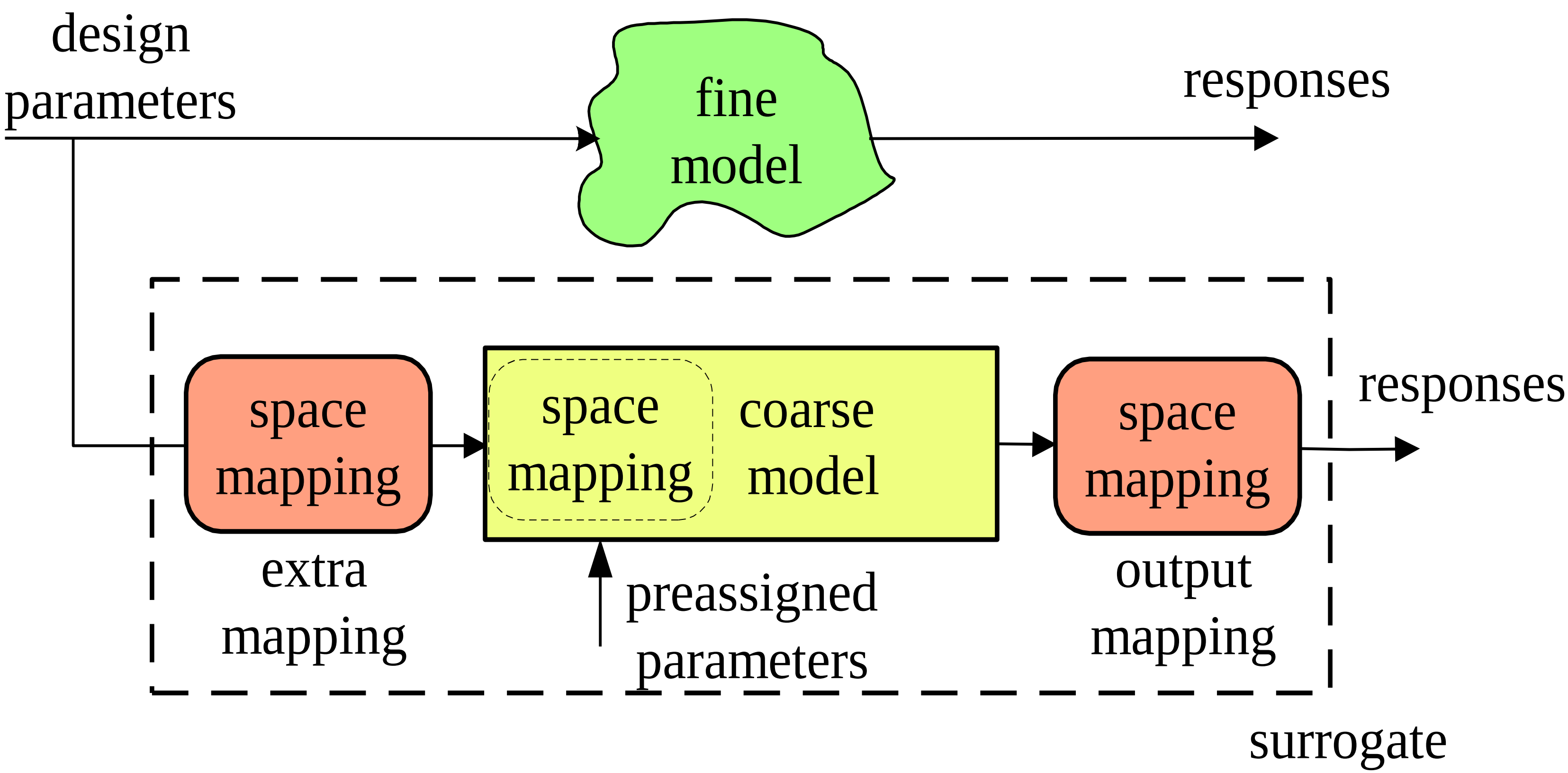
(*Bandler, 2002*)



error = (30–29.7)/30×100%
=1%

Implicit, Extra and Output Space Mappings

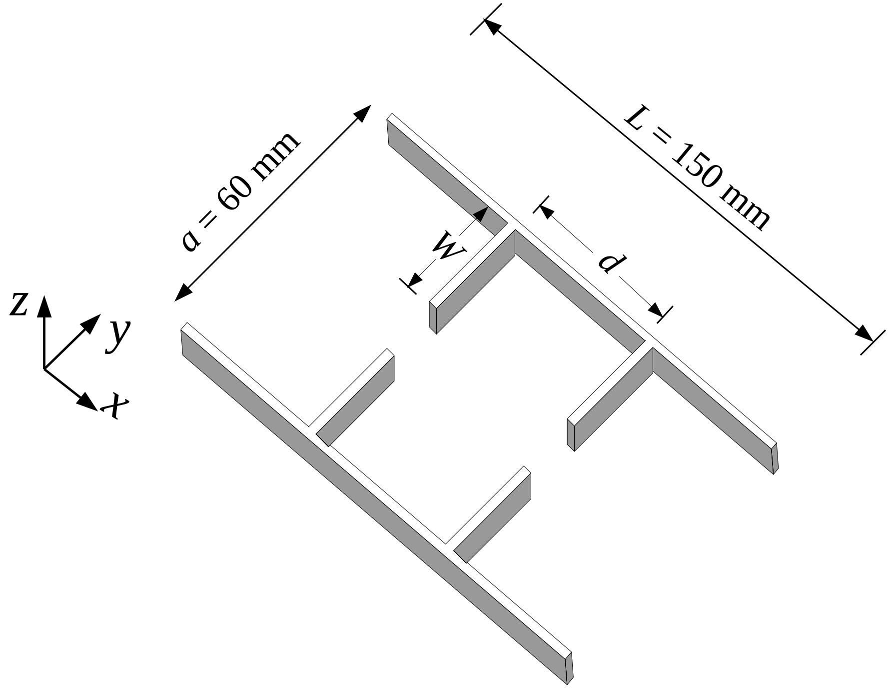
(*Bandler et al., 2003*)



Single Resonator Filter (*Bakr et. al, 2002*)

design of *d* and *W* with the waveguide dimensions fixed
(*a* = 60 mm and *L* = 150 mm)

Matlab implemented 2D TLM simulator is used (*Bakr 2004*)



Single Resonator Filter SM Design (*Bandler et al., 2005*)

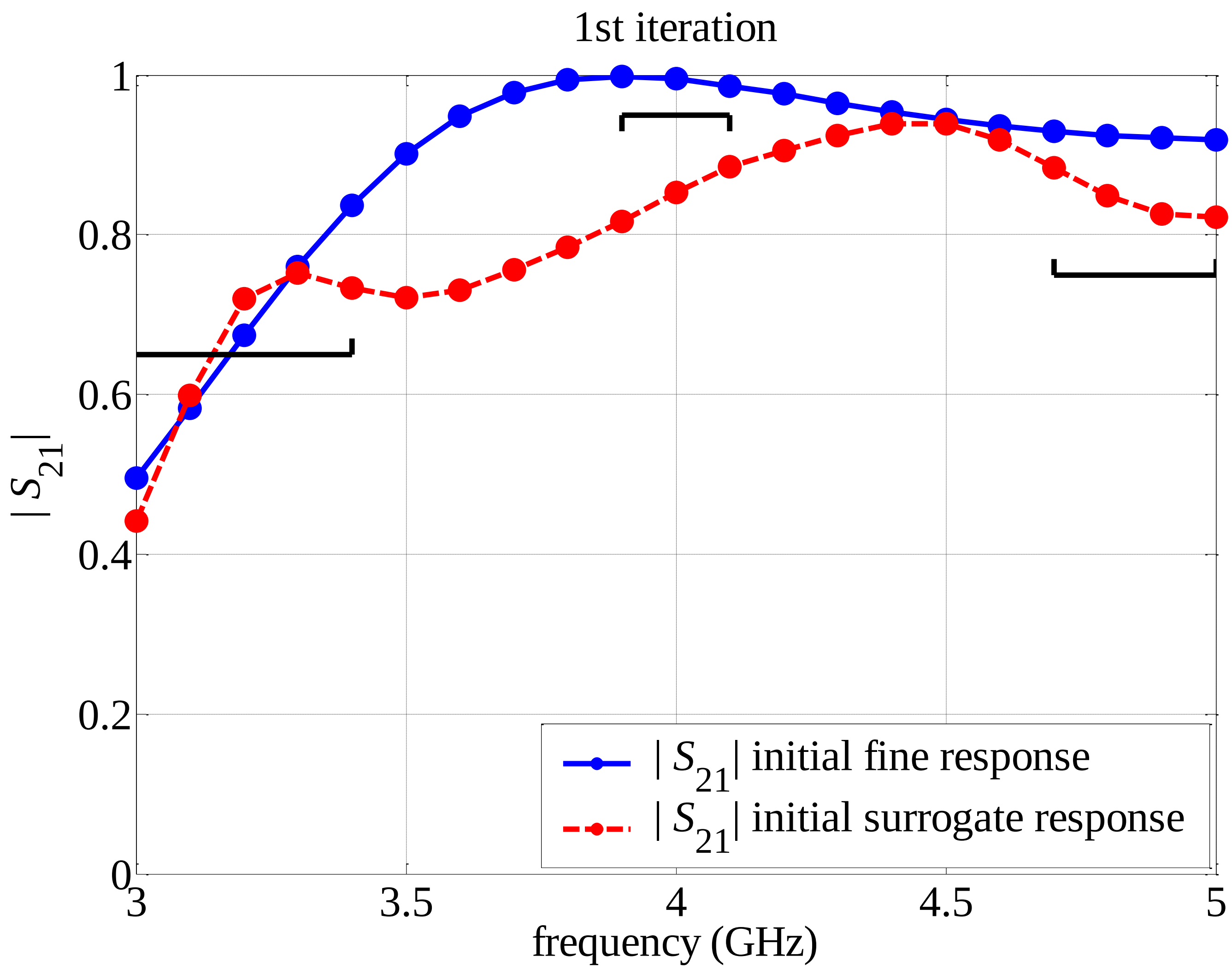
3.0 GHz $\leq \omega \leq$ 5.0 GHz with 0.1GHz step (21 points)

design parameters $x_f = [d \;\; W]^T$

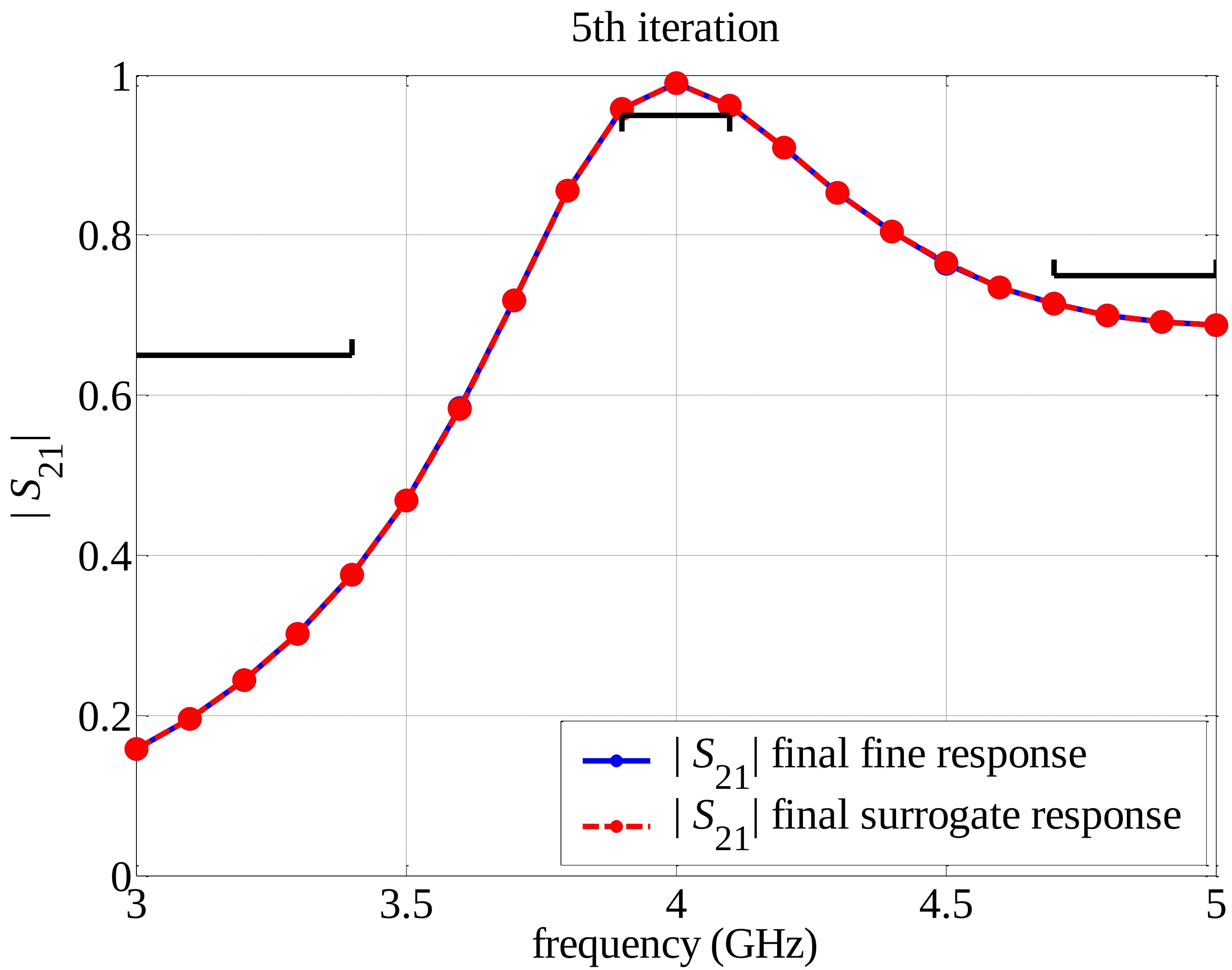
preassigned parameter $x = \varepsilon_r$

Fine Model	**Coarse Model**
$dx = dy = 1$ mm	$dx = dy = 5$ mm
$\Delta d = 2dx$, $\Delta W = dy$	$\Delta d = 2dx$, $\Delta W = dy$
$Nx = 150$	$Nx = 30$
$Ny = 30$	$Ny = 6$
Johns boundary	absorbing boundary at 4 GHz

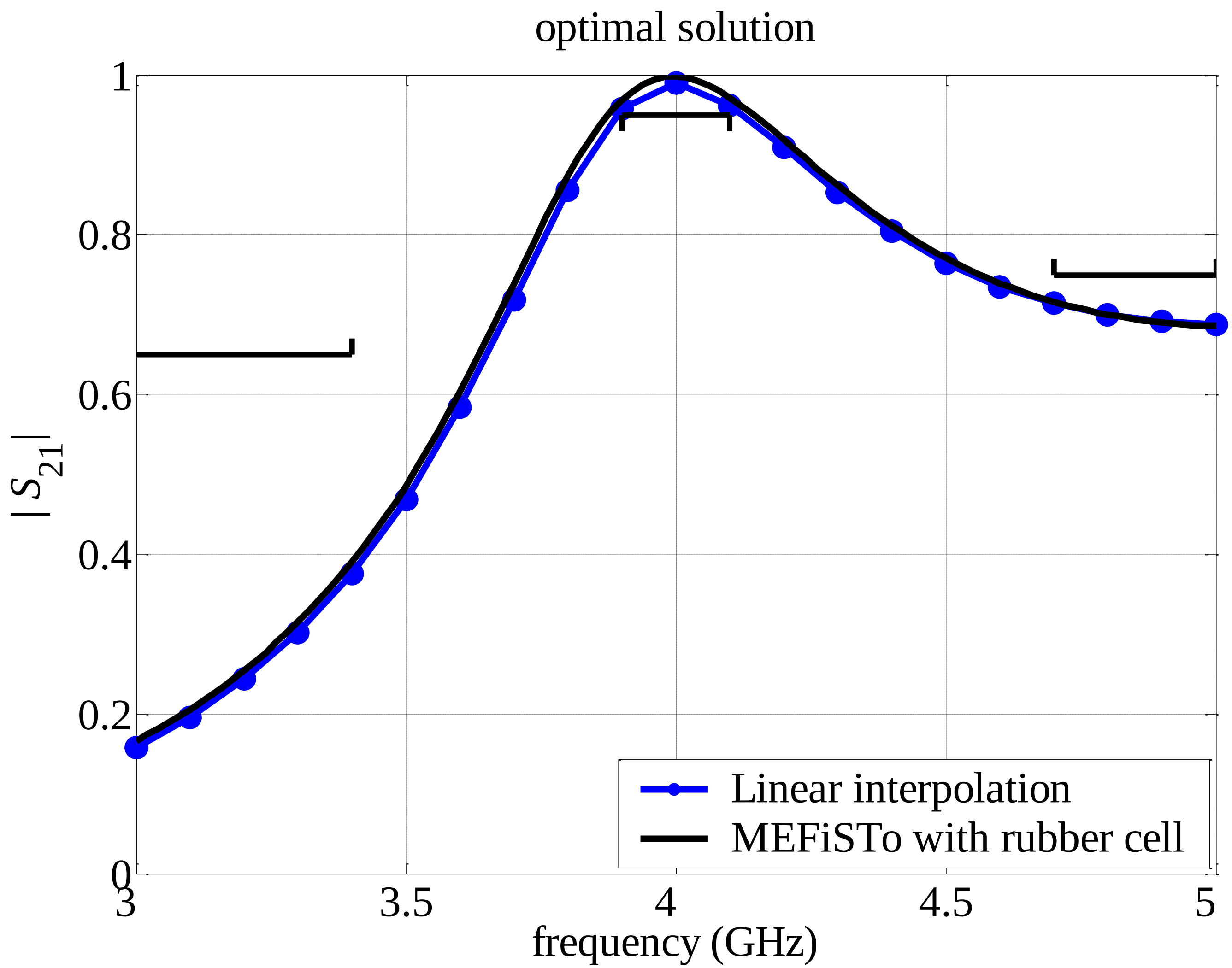
Single Resonator Filter SM Design (*Bandler et al., 2005*)



Single Resonator Filter SM Design (*Bandler et al., 2005*)



Single Resonator Filter Final SM Design (*Bandler et al., 2005*)



The Brain's Automatic Pilot
(*Sandra Blakeslee, The New York Times,*
International Herald Tribune, February 21, 2002, p.7)

[certain brain] circuits are used by the human brain
to assess social rewards …

…findings [by neuroscientists] …challenge the notion
that people always make conscious choices
about what they want and how to obtain it.

Gregory Berns (Emory University School of Medicine):
… most decisions are made subconsciously
with many gradations of awareness.

The Brain's Automatic Pilot
(*Sandra Blakeslee, The New York Times,*
International Herald Tribune, February 21, 2002, p.7)

P. Read Montague (Baylor College of Medicine): … how did evolution create a brain that could make … distinctions … [about] …what it must pay conscious attention to?

… the brain has evolved to shape itself, starting in infancy, according to what it encounters in the external world.

… much of the world is predictable: buildings usually stay in one place, gravity makes objects fall …

The Brain's Automatic Pilot
(*Sandra Blakeslee, The New York Times,*
International Herald Tribune, February 21, 2002, p.7)

As children grow, their brains build internal models
of everything they encounter, gradually learning to identify objects …

… as new information flows into it … the brain automatically
compares it with what it already knows.

… if there is a surprise …. the mismatch … instantly shifts
the brain into a new state.

Drawing on past experience … a decision is made …

Bandler's Conjecture No. 1

Space Mapping is a natural mechanism for the brain to relate objects or images with other objects, images, reality, or experience

Bandler's Conjecture No. 2

brains of "clever", experienced or intuitive individuals employ a Broyden-like update in the Space Mapping process

Bandler's Conjecture No. 3

"experienced" engineering designers, knowingly or not, routinely employ Space Mapping to achieve complex designs

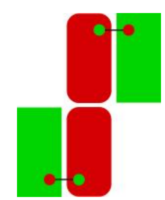
Space Mapping Technology: Current and Future Work

new framework and optimization algorithms
rigorous convergence proofs (with Dr. S. Koziel, collaboration with Dr. K. Madsen, DTU, Denmark)

methodologies for device and component model enhancement (collaboration with Dr. Q.J. Zhang, Carleton University)

TLM-based modeling and design (with Dr. M.H. Bakr)

exploitation of adjoint sensitivities for coarse and fine model EM solvers (with Drs. M.H. Bakr and N.K. Nikolova)



Work in Progress: Convergence Theory, Algorithms, User-Friendly Software for SM-based Modeling and Optimization

convergence results for the original, output and implicit SM optimization algorithms

unified SM formulations and algorithms

new and robust SM optimization algorithms

advanced SM modeling methodologies

commercially-available, user-friendly software engine for SM optimization/modeling with sockets to drive popular simulators (*Bandler Corporation, 2005*)

Preliminary Announcement

SECOND INTERNATIONAL WORKSHOP ON SURROGATE MODELING AND SPACE MAPPING FOR ENGINEERING OPTIMIZATION

John Bandler and Kaj Madsen, Organizers

Thursday, November 9 to Saturday, November 11, 2006
Technical University of Denmark
Lyngby, Denmark

Invited speakers to be announced

PROPOSAL FOR A FULL DAY WORKSHOP
IMS 2006 (SAN FRANSISCO)

Microwave Component Design Using Space Mapping Technology

Proposed Sponsors:

- MTT-1 Computer-Aided Design
- MTT-8 Filters and Networks
- MTT-15 Microwave Field Theory

Organizer: John W. Bandler, Bandler Corporation, Canada

Possible Speakers:

- John Bandler, Bandler Corporation
- Vicente Boria, Universidad Politécnica de Valencia, Spain
- Slawomir Koziel, McMaster University, Canada
- Kaj Madsen, Technical University of Denmark, Denmark
- Jim Rautio, Sonnet Software
- Dan Swanson, M/A-COM
- Ming Yu and M.A. Ismail, Com Dev, Canada
- Ke-Li Wu, The Chinese University of Hong Kong
- Q.J. Zhang, Carleton University, Canada