FULLY AUTOMATED SPACE MAPPING OPTIMIZATION OF 3D STRUCTURES

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Overview of the Presentation

overview of Aggressive Space Mapping™

generic SM update loop

model-specific parameter extraction loop

two-level Datapipe™ architecture

automated SM optimization of an HTS filter

automated SM optimization of waveguide transformers

EM optimization with the HFSS 3D simulator

multi-point parameter extraction procedure

Introduction

Space Mapping combines the computational expediency of empirical engineering models and the acclaimed accuracy of EM simulators

aggressive SM progressively refines the mapping using the Broyden update

implementation of SM requires two nested iterative loops

parameter extraction is a crucial step in SM optimization

- we investigate the impact of its uniqueness on the convergence of aggressive SM

- we consider a multi-point technique

The Space Mapping Concept

consider models in two distinct spaces

the optimization space X_{OS} (fast/coarse models)

the EM space X_{EM} (accurate/fine models)

SM exploits a mapping P between X_{OS} and X_{EM}

$$x_{OS} = P(x_{EM})$$

such that the respective model responses match

$$R_{OS}(P(x_{EM})) \approx R_{EM}(x_{EM})$$

we perform optimization in X_{OS} to obtain x_{OS}^*

the SM solution is determined as

$$\bar{x}_{EM} = P^{-1}(x_{OS}^*)$$

P is found iteratively starting from $x_{EM}^1 = x_{OS}^*$

Generic Aggressive Space Mapping Loop

the next iterate is found by a quasi-Newton step

$$x_{EM}^{i+1} = x_{EM}^{i} + (B^{i})^{-1}(x_{OS}^{*} - x_{OS}^{i})$$

using an approximate Jacobian B^i

B^i is subsequently updated using the Broyden formula

Parameter Extraction Optimization Loop

at the ith step, the X_{EM} model is simulated at the current parameter values x_{EM}^{i}

if the X_{EM} model is not satisfactory we perform parameter extraction of the X_{OS} model to find x_{OS}^{i} which minimizes

$$\| R_{OS}(x_{OS}^{i}) - R_{EM}(x_{EM}^{i}) \|$$

Implementation of Aggressive Space Mapping

we fully automate the aggressive SM strategy using a two-level Datapipe architecture

two iterative loops with different sets of variables

the outer loop updates x_{EM}

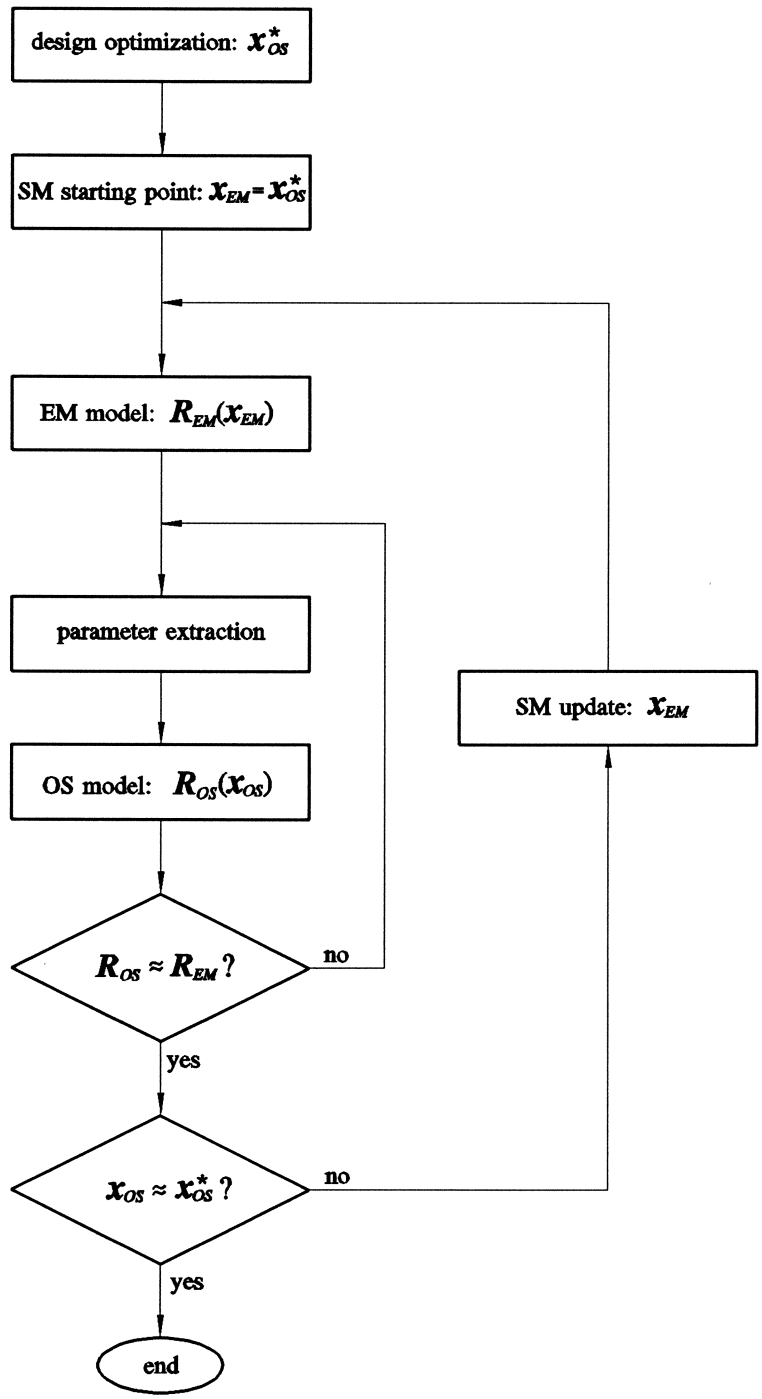
the inner loop performs parameter extraction of the x_{OS} model (x^i_{EM} is held constant)

explicitly depends on the specific models involved

Datapipe is utilized here to connect external simulators (models) to the optimization environment

Datapipe facilitates the nested loops in separate processes and maintains a functional link between their results

Automated Aggressive Space Mapping



HTS Filter Design by SM Optimization
(*Bandler et al., 1994*)

the empirical microstrip coupled-line model (the X_{OS} model) is not accurate for the high dielectric constant of the lanthanum aluminate substrate (more than 23)

Sonnet's ***em*** used as the X_{EM} model

approximately 1 CPU hour on a Sun SPARCstation 10 is needed to simulate the filter at a single frequency with fine resolution

aggressive SM applied to optimize the filter

six optimization variables

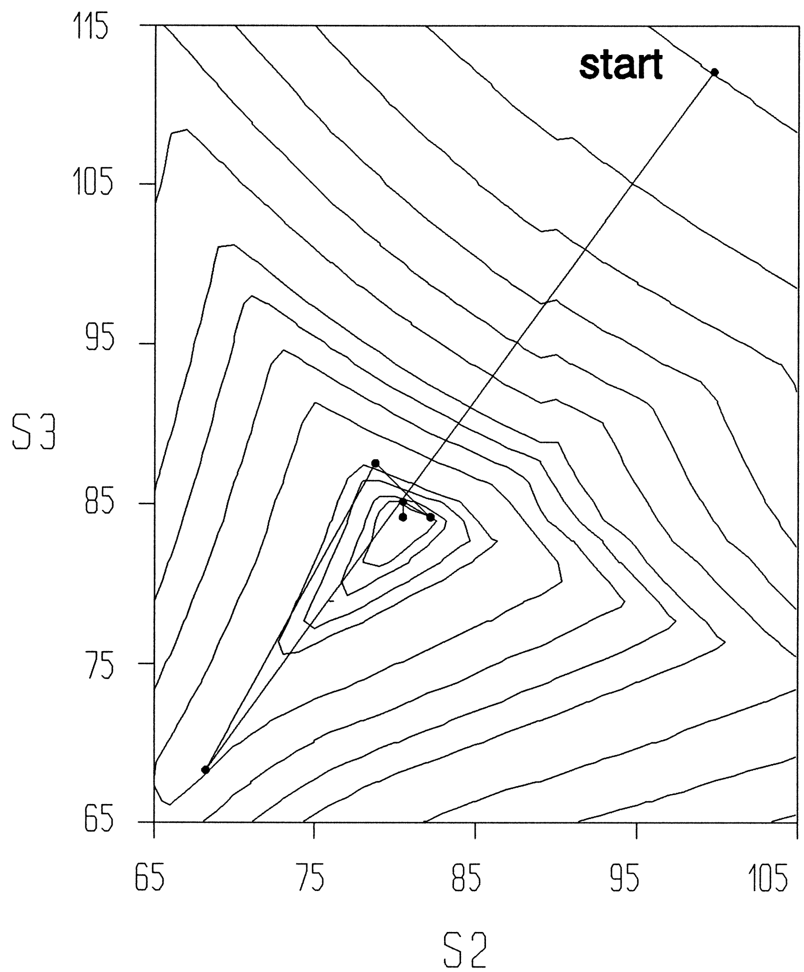
the coupled-line section lengths L_1, L_2 and L_3

the section spacings S_1, S_2 and S_3

the automated SM optimization confirms earlier results

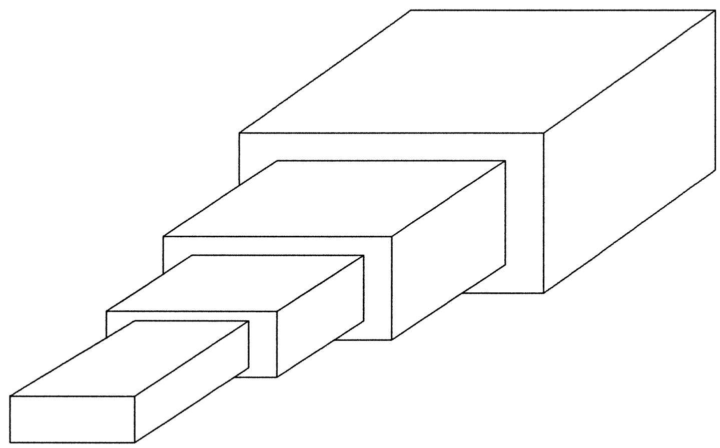
SM Trace for the HTS Filter

trace of the steps taken by $\boldsymbol{x}_{EM}$ projected onto minimax contours in the S_2-S_3 plane (spacings between the lines)



SM Optimization of Waveguide Transformers

a typical two-section waveguide transformer



two cases of Space Mapping used to align

(a) an ideal empirical model and a non-ideal empirical model (*Bandler, 1969*)

(b) an empirical model and HFSS simulations

three designs: 2, 3 and 7 sections

the variables are the heights and lengths of the waveguide sections

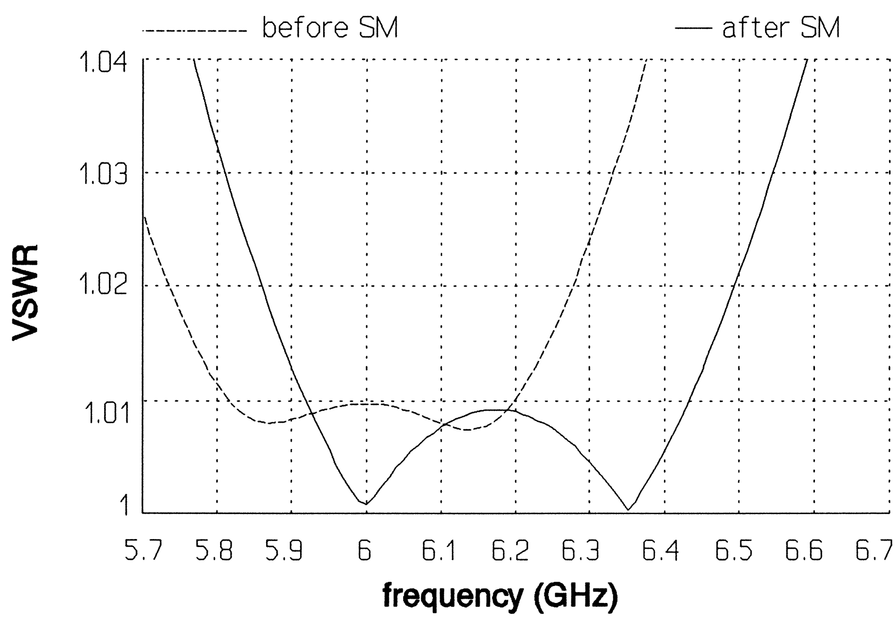
SM Design of a Two-Section Waveguide Transformer

SM between two empirical models (*Bandler, 1969*)

an ideal model which neglects the junction discontinuity (coarse)

a non-ideal model which includes the junction discontinuity (fine)

VSWR responses of the fine model before and after SM optimization



the response after 7 SM iterations is indistinguishable from the optimal ideal response

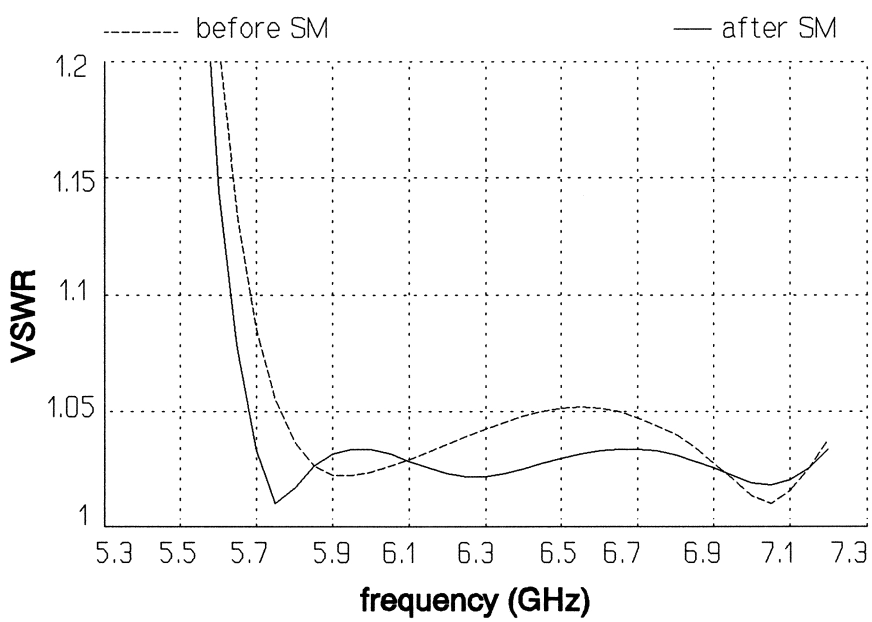
SM Design of a Three-Section Waveguide Transformer

SM between two empirical models (*Bandler, 1969*)

an ideal model which neglects the junction discontinuity (coarse)

a non-ideal model which includes the junction discontinuity (fine)

VSWR responses of the fine model before and after SM optimization



the response after 6 SM iterations is indistinguishable from the optimal ideal response

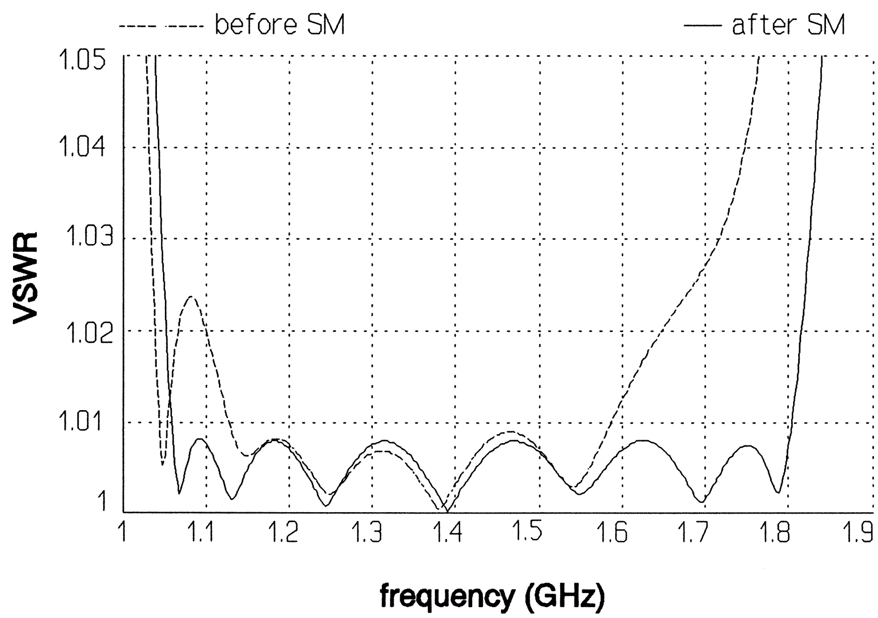
SM Design of a Seven-Section Waveguide Transformer

SM between two empirical models (*Bandler, 1969*)

an ideal model which neglects the junction discontinuity (coarse)

a non-ideal model which includes the junction discontinuity (fine)

VSWR responses of the fine model before and after SM optimization



the response after 5 SM iterations is indistinguishable from the optimal ideal response

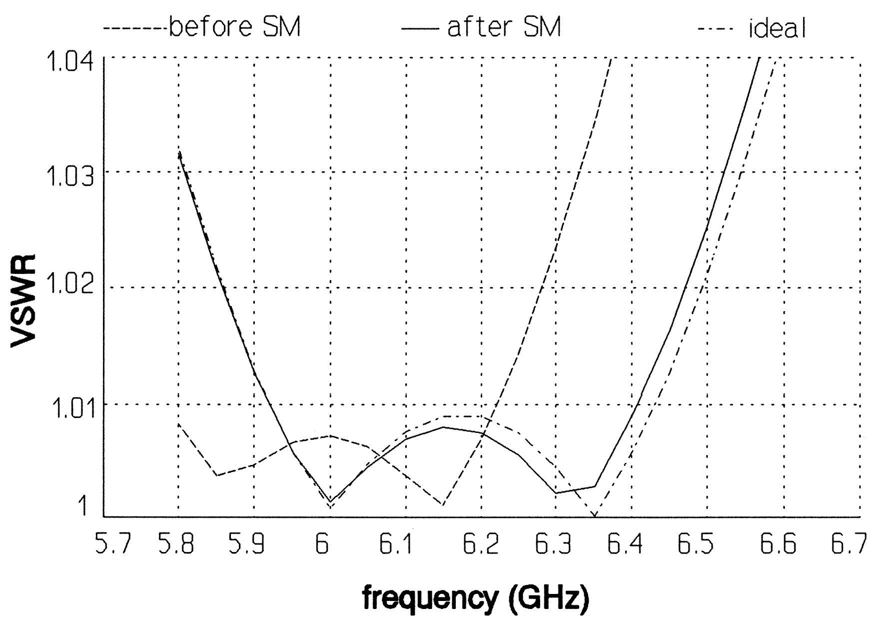
SM Design of a Two-Section Transformer Using HFSS

SM between an empirical model and HFSS simulations

an ideal empirical model (coarse) (*Bandler, 1969*)

the 3D structure simulator HFSS (fine model)

VSWR responses simulated by HFSS before and after SM optimization



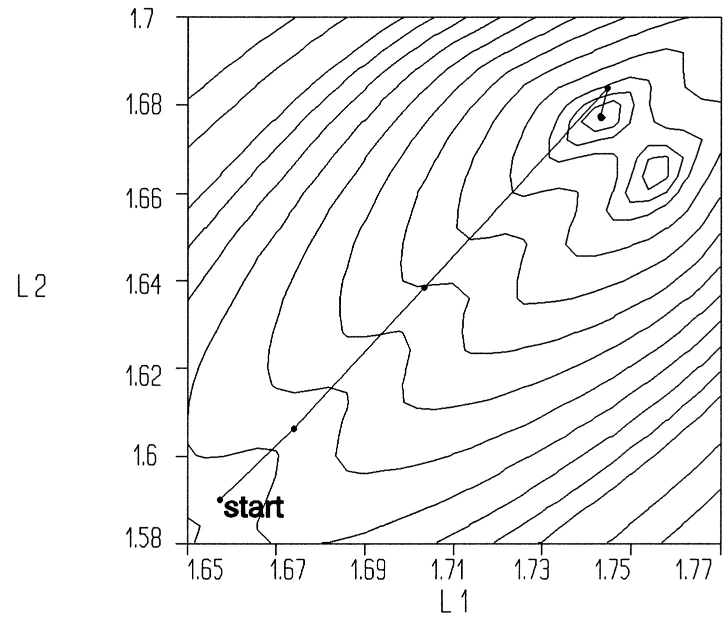
SM required 10 iterations (10 HFSS simulations)

the solution is very close to the target ideal response

Impact of Parameter Extraction Uniqueness

a two-section waveguide transformer

the ℓ_1 contours of the parameter extraction problem with respect to the two section lengths L_1 and L_2



there are two local minima

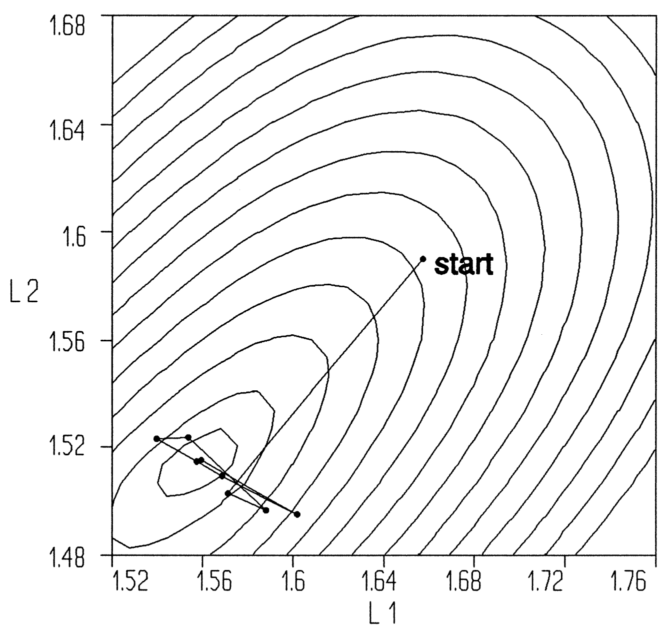
consequently parameter extraction is not unique

SM Oscillations Due to Non-Unique Parameter Extraction

a two-section waveguide transformer

the minimax contours in the L_1-L_2 plane of the fine model

trace of the SM steps of the two-section waveguide transformer



non-unique parameter extraction leads to the SM steps oscillating around the solution

Multi-Point Parameter Extraction

to improve the uniqueness of parameter extraction

instead of minimizing

$$\| R_{OS}(x^i_{OS}) - R_{EM}(x^i_{EM}) \|$$

at a single point, we find x^i_{OS} by minimizing

$$\| R_{OS}(x^i_{OS} + \Delta x) - R_{EM}(x^i_{EM} + \Delta x) \|$$

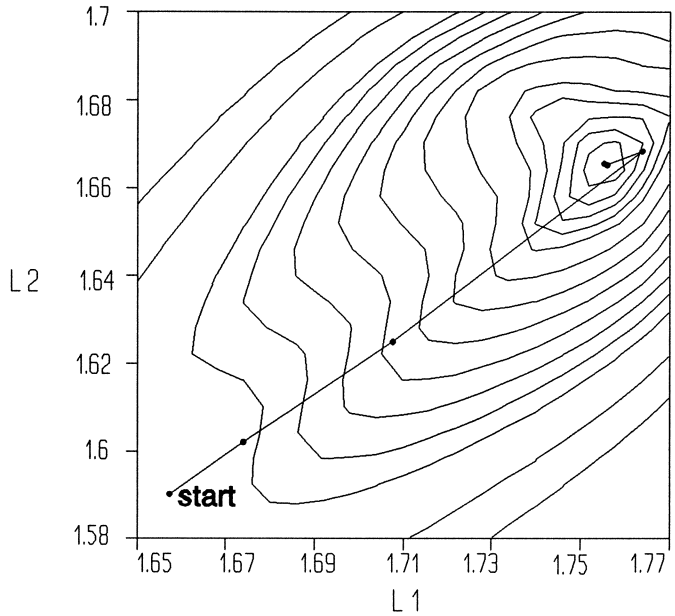
a few perturbations Δx are simultaneously considered

conceptually, we attempt to match not only the responses, but also first-order changes

we have exploited a similar concept in multi-circuit modeling (*Bandler, Chen and Daijavad, 1986*)

Improved Uniqueness of Parameter Extraction

the ℓ_1 contours for three-point parameter extraction



a unique solution is achieved

the price may be an increased number of EM simulations

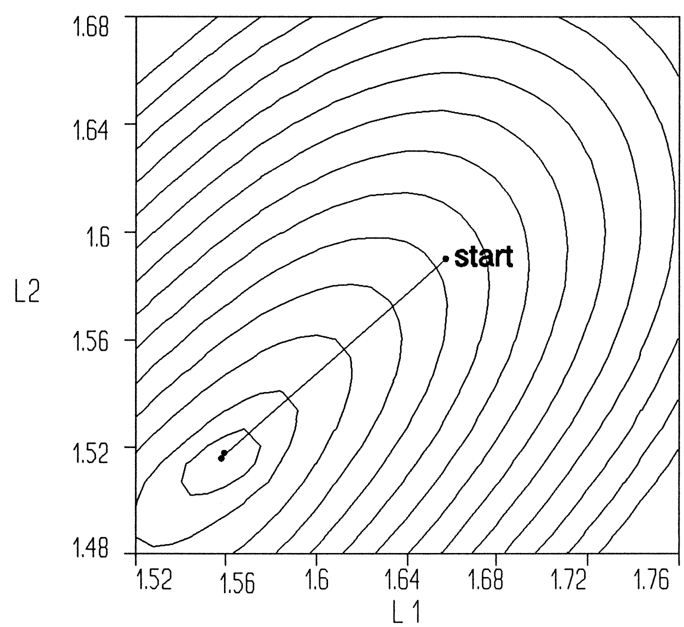
more EM simulations are needed in parameter extraction

however, the overall number of iterations may be reduced

Improved Convergence of SM Iterations

SM trace corresponding the multi-point parameter extraction method

the minimax contours in the L_1-L_2 plane



the convergence of the SM iterations is dramatically improved

Conclusions

Space Mapping promises the accuracy of EM simulation and the speed of circuit-level optimization

new results of automating the steps in aggressive SM

we extend the automated SM optimization to waveguide structures

for the first time - results of driving HFSS to optimize 3D structures

we have demonstrated the importance of unique parameter extraction in the SM process

the multi-point approach enhances the prospect of a unique solution

we believe that the automation will make the benefits of the SM approach more tangible

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