INTELLIGENT DRIVERS AND INTERFACES TO ELECTROMAGNETIC SIMULATORS FOR DESIGN OPTIMIZATION

J.W. Bandler

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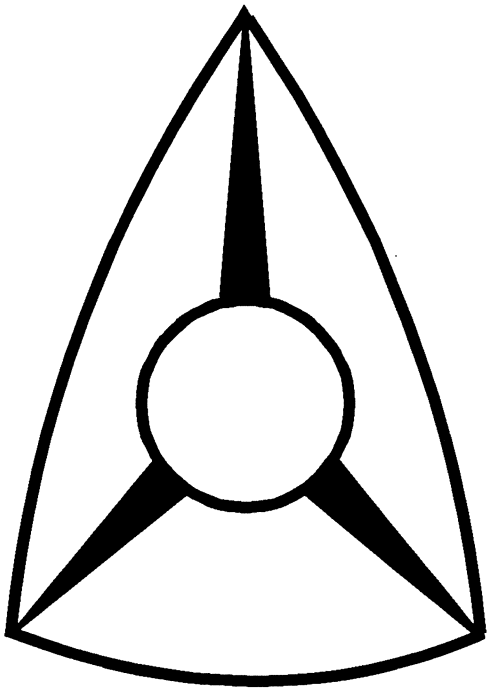


presented at

DARPA ETO Technical Interchange Meeting
for Common Standards for Interfacing TCAD Modeling and Analysis Tools
Arlington, VA, September 26, 1996

Introduction

microwave CAD systems must link geometry, layout, physical and process parameters with performance, yield and system specifications

hierarchically structured CAD systems must integrate electromagnetic (EM) theory, circuit theory and system theory

fast, predictable, physics-based modeling and simulation of devices and circuits are important aspects of manufacturable mm-wave designs

CAD technology must account for statistical uncertainties and parameter spreads

CAD modules must facilitate an effective path from process, physical or geometrical description to a yield-driven, optimization-oriented design environment

First-Pass Success Approach

performance *and* cost specifications

automated optimization

accurate simulation models taking into account

- material and dimensional constraints
- operating environment
- production tolerances

Situations Needing Better Simulation Methodology

satellite system environmental temperature variations

cutting cost by lowering machining precision requirement

self-heating in high-density circuits

modulated and transient high-frequency signals

EM proximity couplings

Milestones VI

Space Mapping™ - a fundamental new theory for design with CPU intensive simulators (1994)

"CAD review: the 7 GHz doubler circuit" by MEE (1994)

optimization of planar structures with arbitrary geometry (1994)

breakthrough Geometry Capture™ technique (1995)

aggressive Space Mapping™ for EM design (1995)

cost-driven physics-based large-signal simultaneous device and circuit design (1995)

integrated harmonic balance and EM optimization (1995)

novel heterogeneous parallel yield-driven EM CAD (1995)

mixed-domain multi-simulator statistical parameter extraction and yield-driven design (1995)

full-day MTT-S workshop on Automated Circuit Design Using Electromagnetic Simulators (Arndt, Bandler, Chen, Hoefer, Jain, Jansen, Pavio, Pucel, Sorrentino, Swanson, 1995)

Milestones VII

explosion of development and use of optimization-based technology for automated circuit design with EM simulators (1994, 1995)

Network Datapipe™ connection of OSA90/hope™ with Hoefer's TLM electromagnetic field simulators on massively parallel computers (1995)

Datapipe™ connections of OSA90/hope™ with Sorrentino's mode-matching electromagnetic field simulators with adjoint sensitivities (1995)

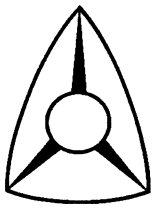
Datapipe™ connection of OSA90/hope™ with Arndt's waveguide component library (1995)

parameterization of arbitrary geometrical structures (1996)

fully-automated Space Mapping™ optimization of 3D structures (1996)

Empipe3D™ connection of OSA90/hope™ with Hewlett-Packard's HFSS and Ansoft's Maxwell® Eminence 3D full-wave simulators (1996)

EmpipeExpress™ connection of OSA90/hope™ with Sonnet's Software's *em*™ field simulator (1996)



O90/hope™ Version 3.5

general nonlinear circuit simulation and optimization

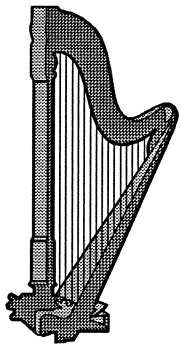
comprehensive optimization/nonlinear modeling

statistical analysis and design

automated Space Mapping optimization

3D visualization, global optimization

Datapipe connection to user's in-house simulators



HarPE™ Version 2.0

device characterization, simulation and optimization

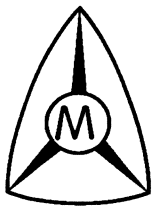
FET, bipolar, HEMT, HBT, thermal modeling

parameter extraction, statistical modeling

cold and hot measurements

Huber optimization, Monte Carlo analysis

can be invoked from OSA90™ as a child process



Empipe™ Version 3.5

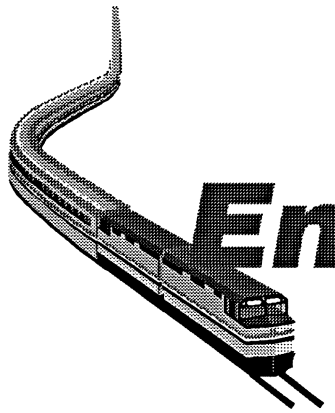
merges OSA90™ and Sonnet's em™ for direct EM optimization

integrates EM analysis into circuit-level optimization

captures and optimizes arbitrary geometries

a library of built-in microstrip elements

intelligent and efficient interpolation and database



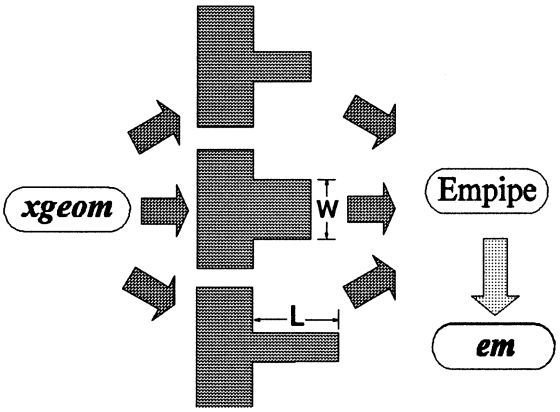
EmpipeExpress

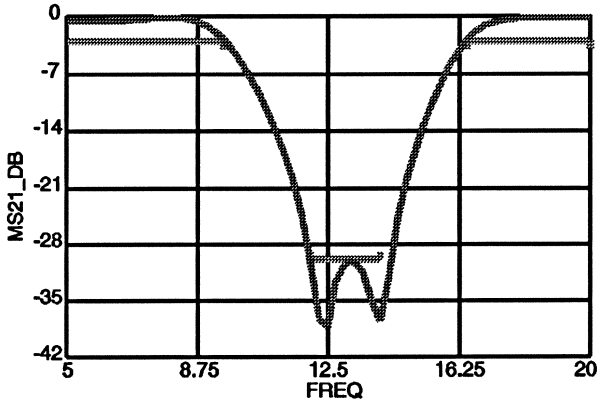
driving Sonnet's *em*

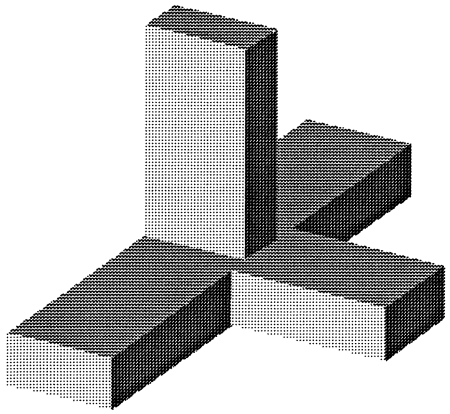
consolidated optimization features

concise, intuitive user interface

Geometry Capture







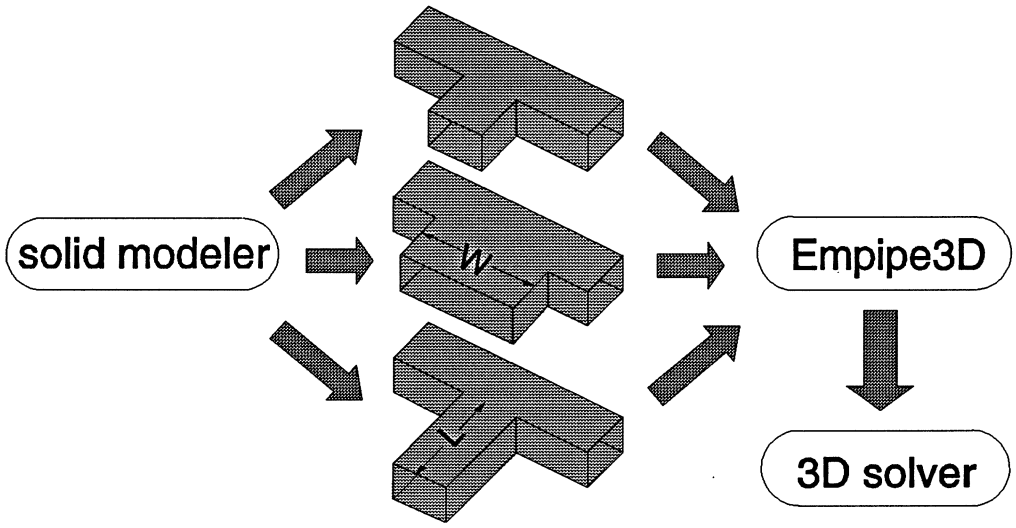
Empipe3D

driving Maxwell Eminence of ANSOFT

and HFSS from hp

automated, efficient optimization

parameterization of arbitrary 3D structures by Geometry Capture



Overview of Presentation

design centering; yield optimization; cost-driven design

integration through Datapipe™

EM optimization

parameterization through Geometry Capture™

parallel computation

Space Mapping™ optimization

OSA's Datapipe™

encapsulating simulators as black-box executables with alphanumeric inputs and outputs

built-in support for network and parallel computing

preprocessing and postprocessing of data

preprocessing of ***x1, x2,*** ...;

FILE="*simulator*"

INPUT=(*text,* ***x1, x2,*** ...)

OUTPUT=(***y1, y2,*** ...);

postprocessing of ***y1, y2,*** ...;

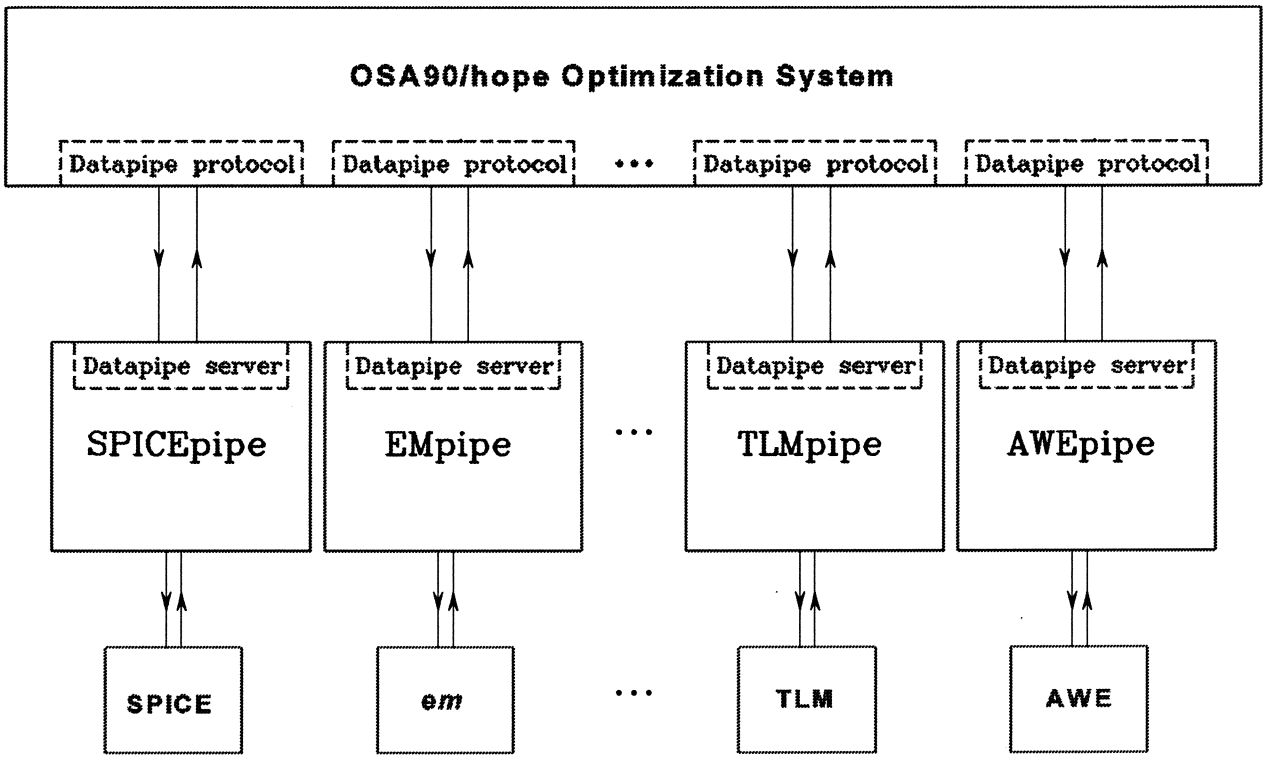
hierarchy of variables

multiple simulators can be combined (serial and parallel)

simultaneous specifications in different domains

symbolic algebra and gradients

OSA's Datapipe™ System



Challenges of Automated EM Optimization
(*Bandler et al., 1993, 1994*)

drastically increased analysis time

discrete nature of some EM solvers

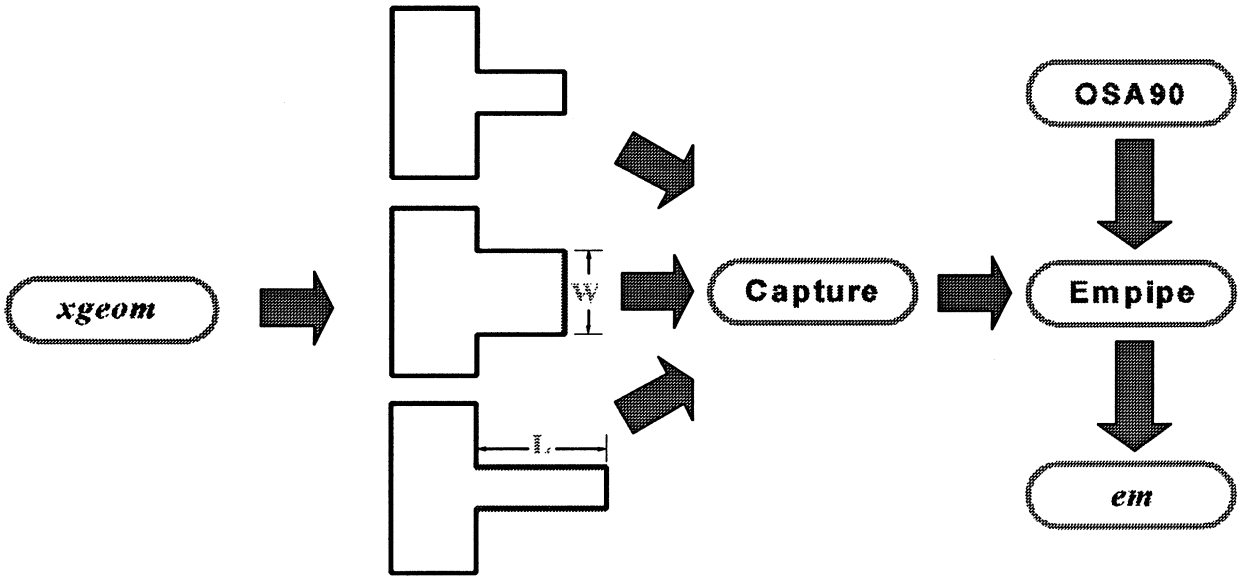
continuity of optimization variables

gradient information

interpolation and modeling

integrated data bases

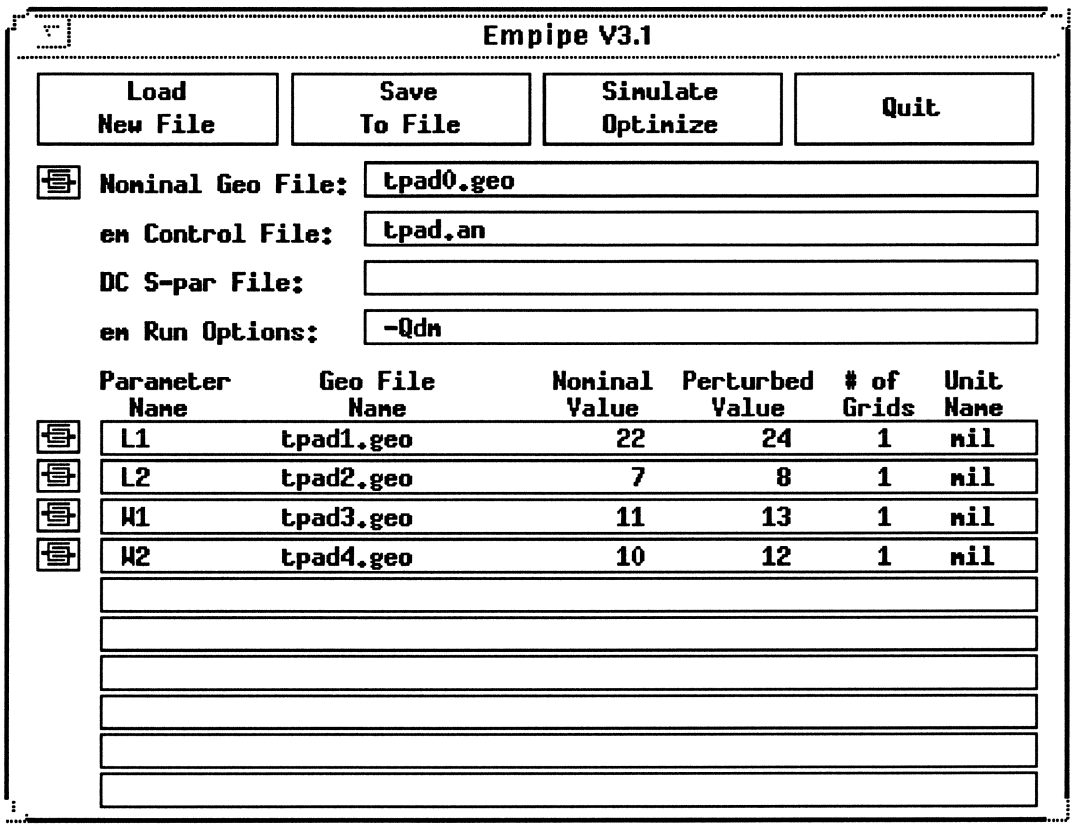
Implementation of Geometry Capture™



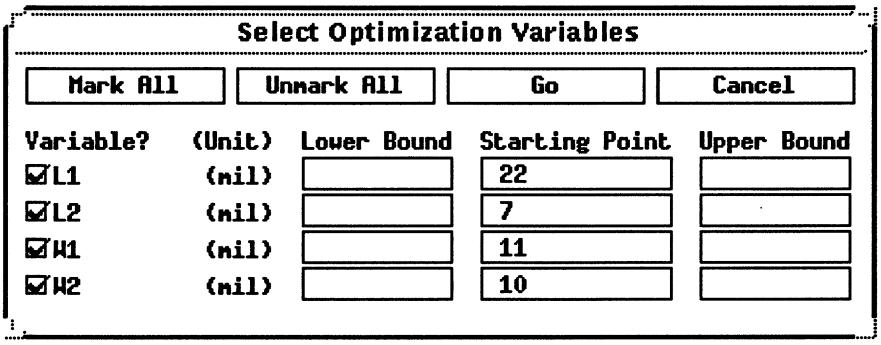
employs a sophisticated algorithm in a manner completely transparent to the user

extremely easy to use

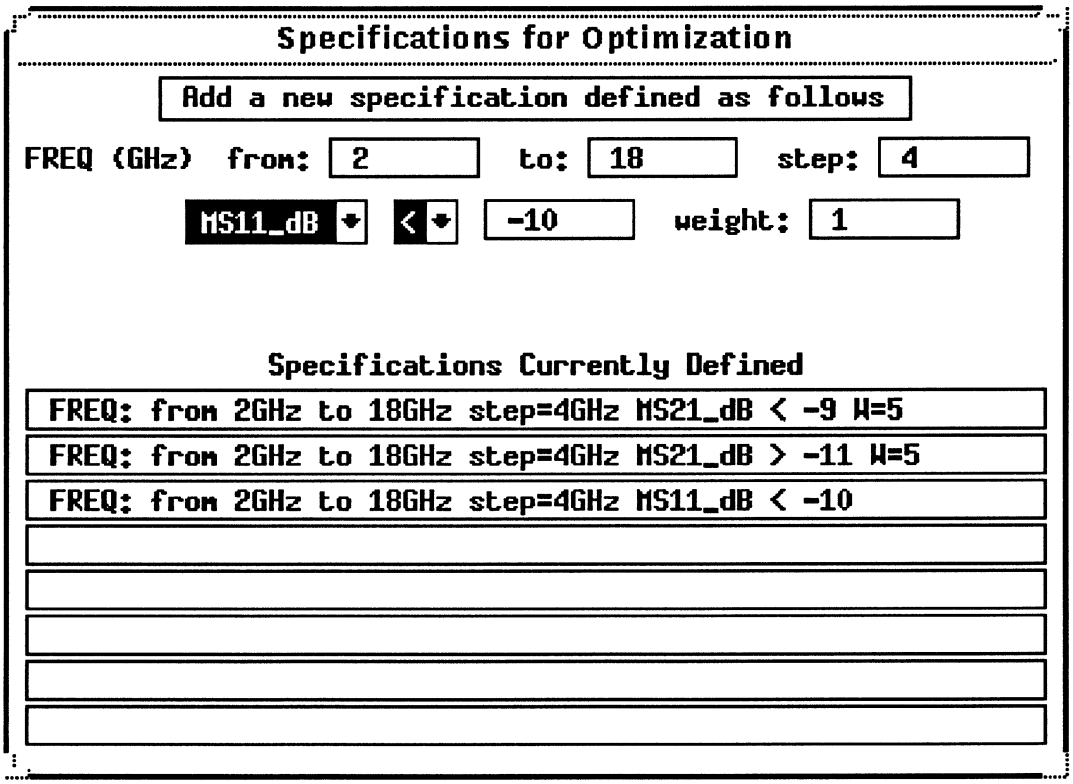
Empipe Geometry Capture™ Form Editor



Select Optimization Variables Windows



Specifications for Optimization Windows



Organization of Parallel Computing

organized by Empipe from one of the networked computers (master host)

using standard UNIX protocols (remote shell and equivalent hosts) an EM analysis is started on each of the available hosts

when the analysis is finished on a host, the next job, if any, is dispatched to that host

EM simulation results are gathered from all the hosts and stored in a data base created on the master host

no platform specific mechanisms

applicable to both local and wide area networks of heterogeneous workstations

Parallel Computing Options

multiprocessor computers and specialized compilers vs. distributing EM analyses over a computer network

the overhead of parallelization is negligible as compared to the CPU-intensive EM analyses

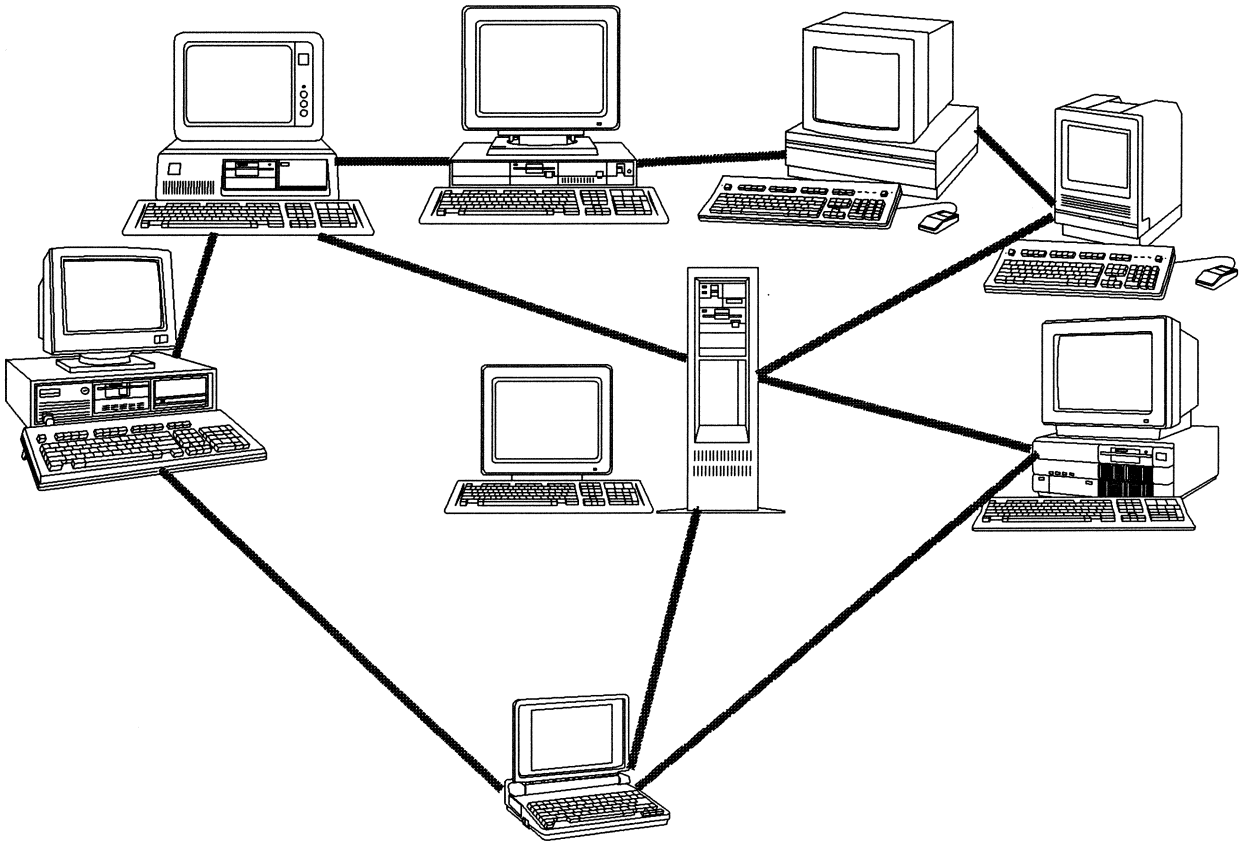
splitting at the component/subcircuit level

suitable when several EM simulation results are needed simultaneously

- off-grid interpolation
- numerical gradient estimation
- multiple outcomes in statistical analysis

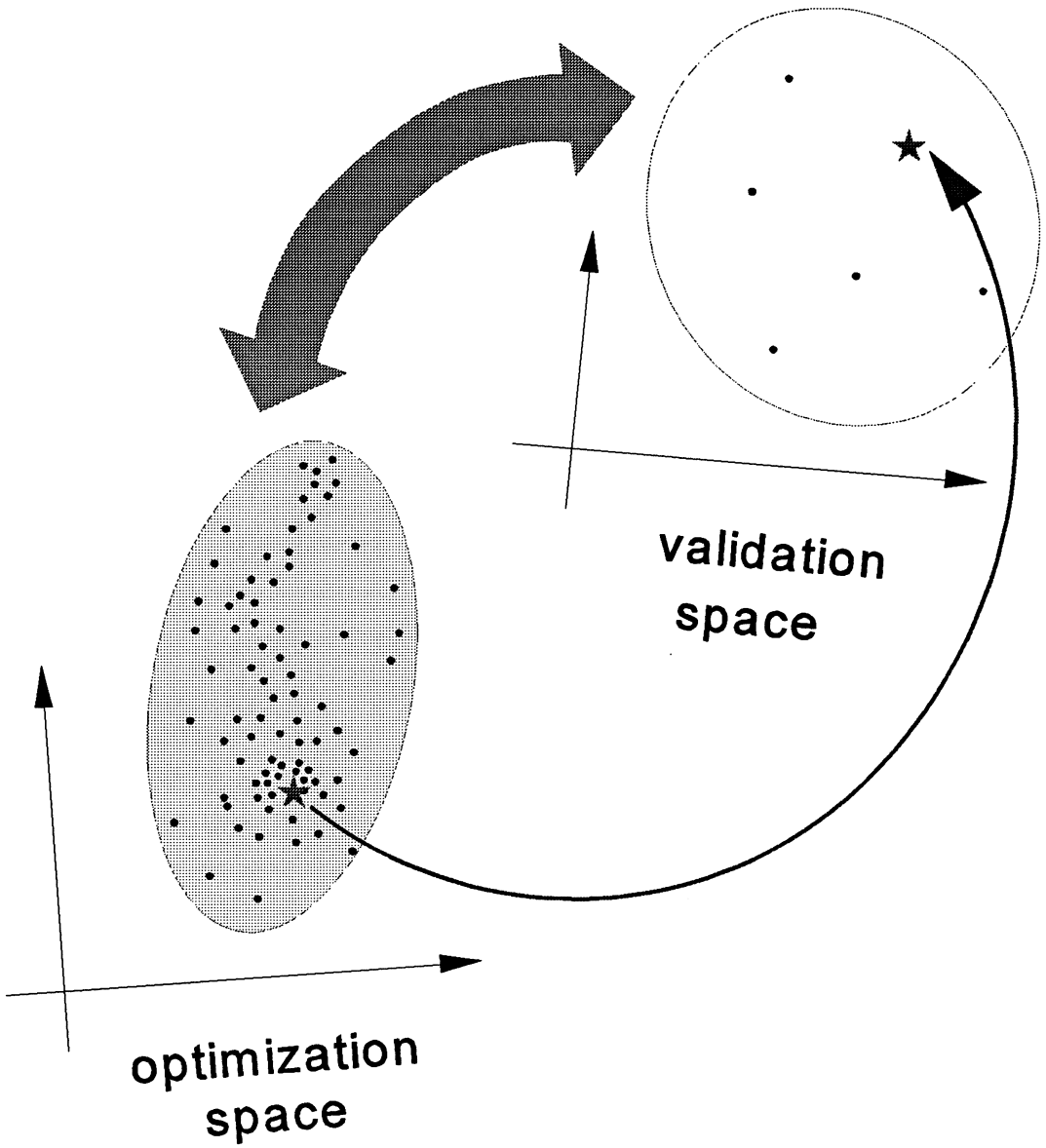
suits best the operational flow of interpolation, optimization and statistical analysis

Heterogeneous Network of Computers

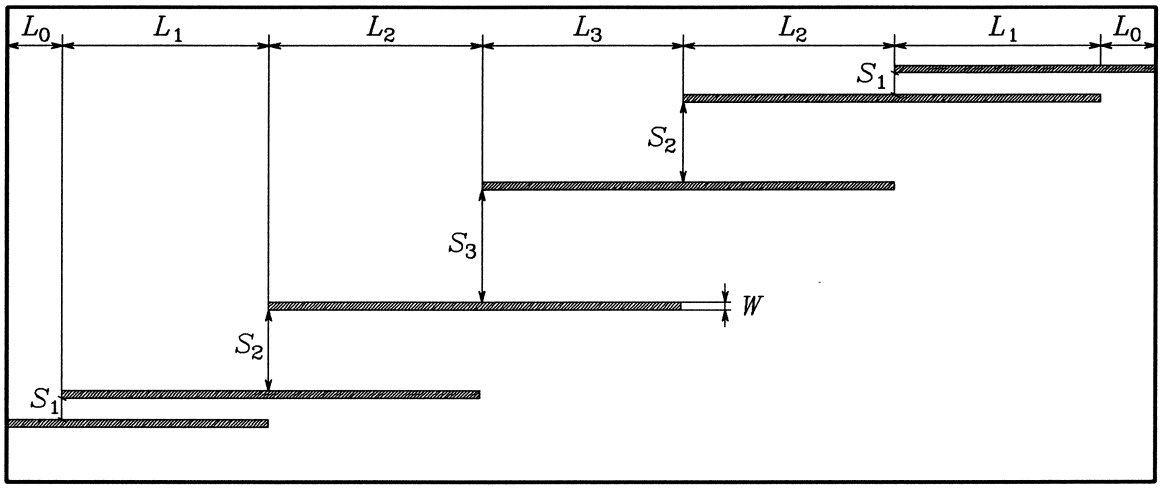


Space Mapping™

(Bandler et al., 1994)



The HTS Quarter-Wave Parallel Coupled-Line Filter
(*Westinghouse, 1993*)



20 mil thick lanthanum aluminate substrate

the dielectric constant is 23.4

the x and y grid sizes for ***em*** simulation are 1.0 and 1.75 mil

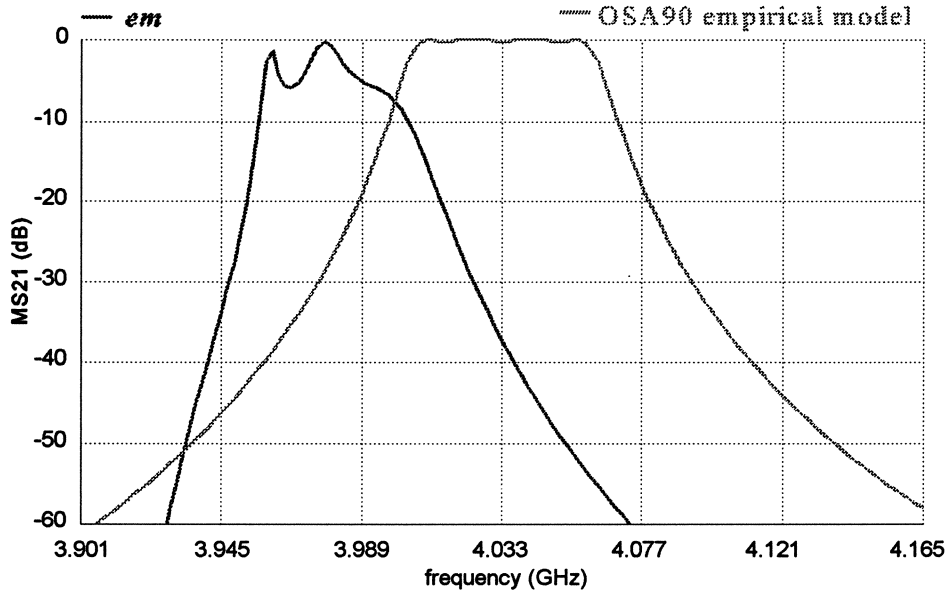
100 elapsed minutes are needed for ***em*** analysis at a single frequency on a Sun SPARCstation 10

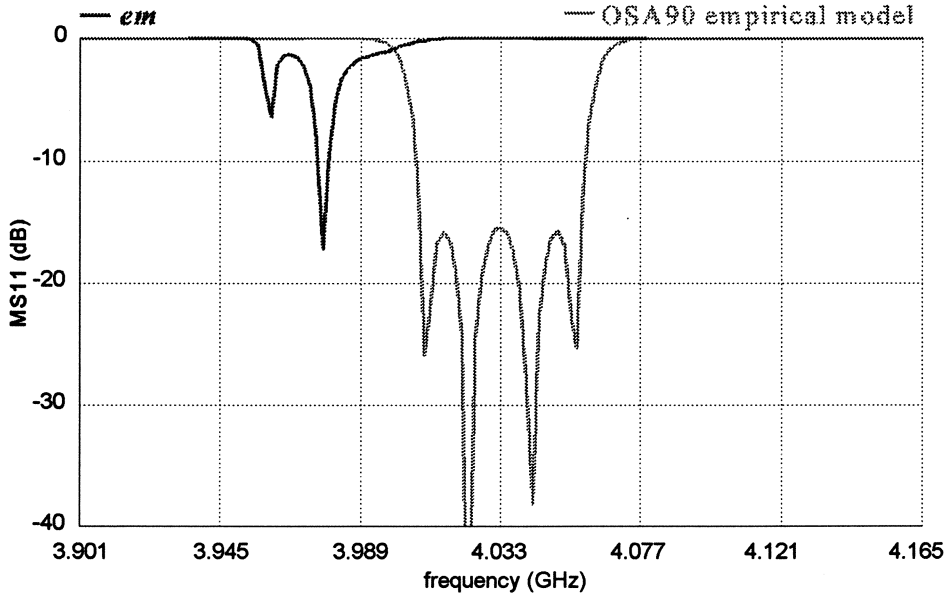
design specifications

$$S_{21} < 0.05 \quad \text{for} \quad f < 3.967 \text{ GHz and } f > 4.099 \text{ GHz}$$

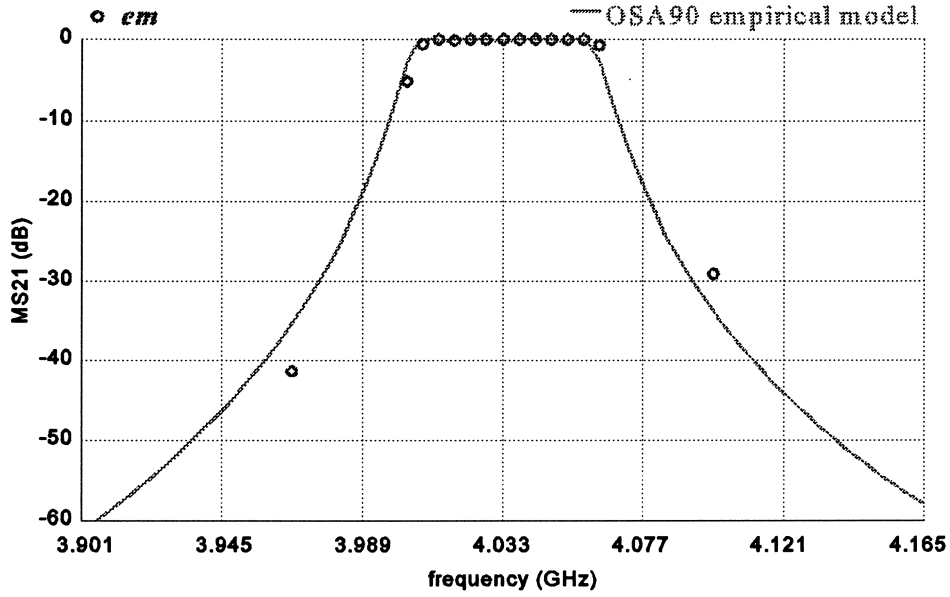
$$S_{21} > 0.95 \quad \text{for} \quad 4.008 \text{ GHz} < f < 4.058 \text{ GHz}$$

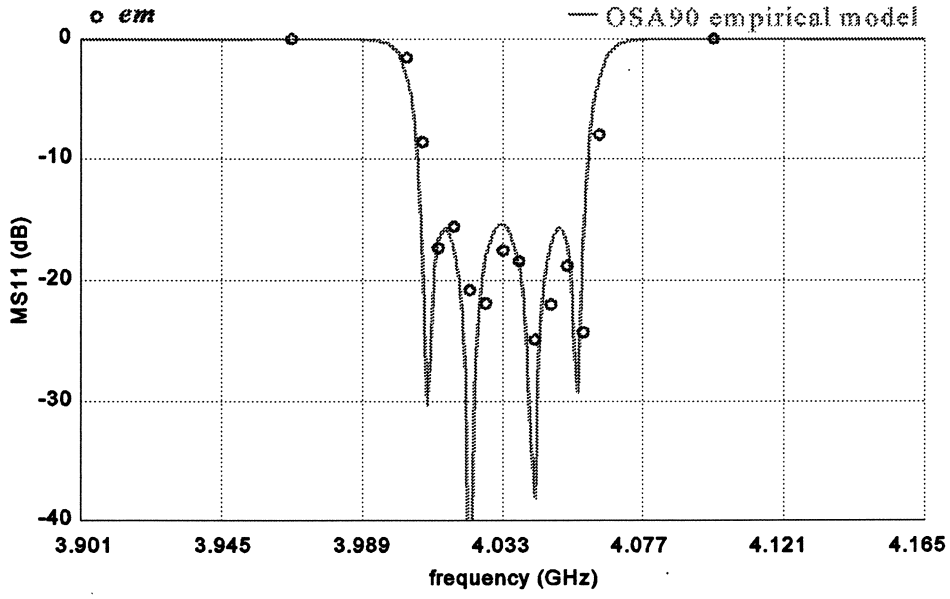
Starting Point of EM Optimization: Design Using Empirical Circuit Model



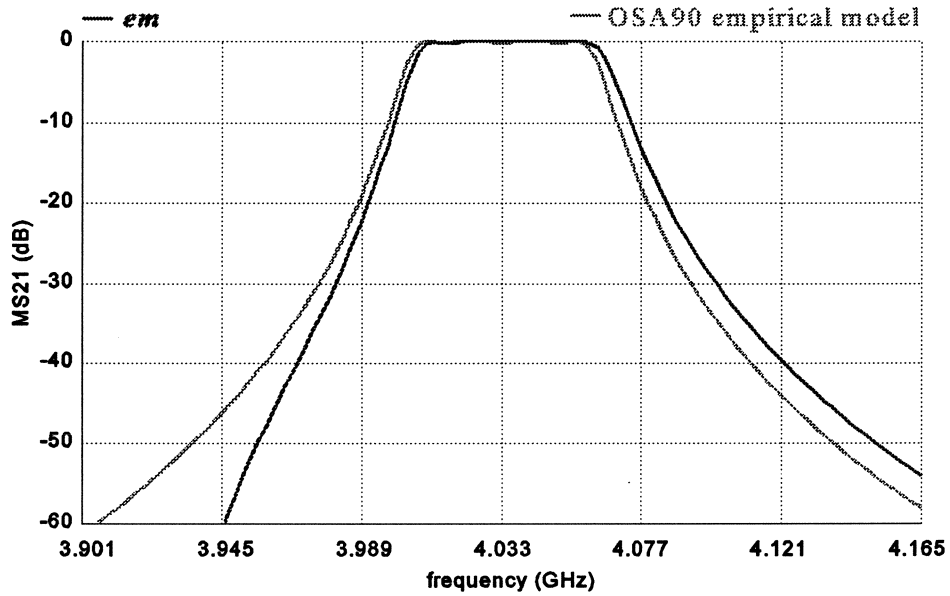


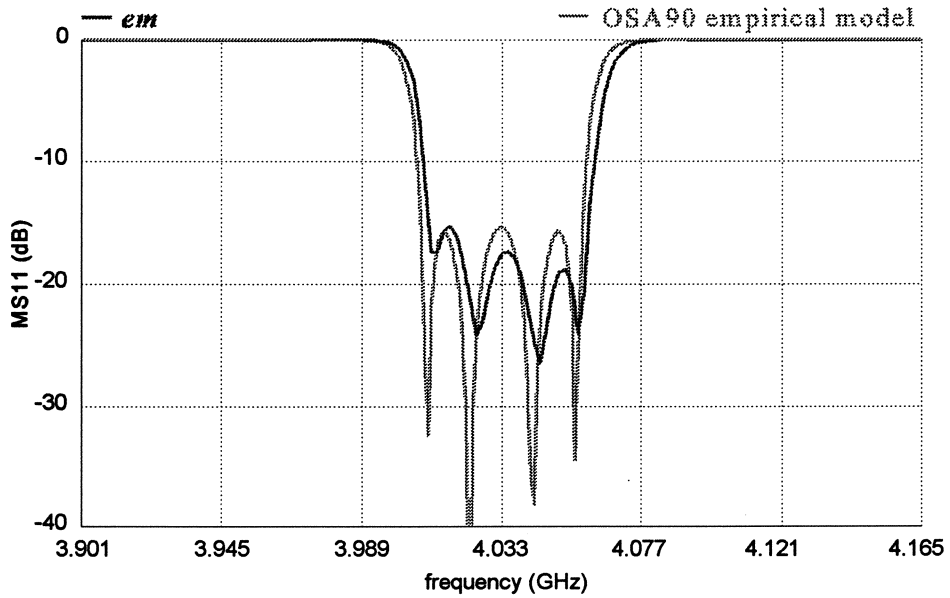
Solution by Aggressive Space Mapping After 3 Iterations



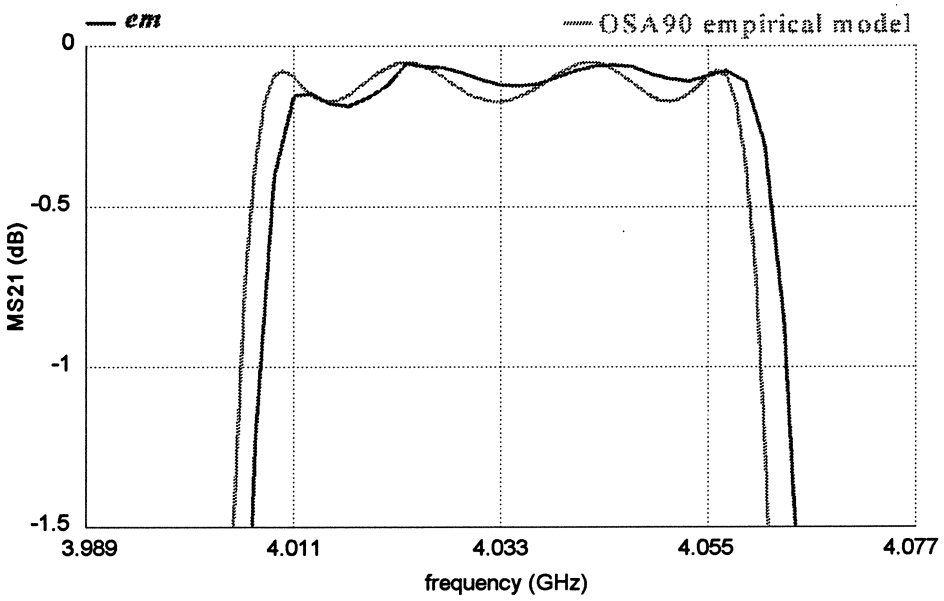


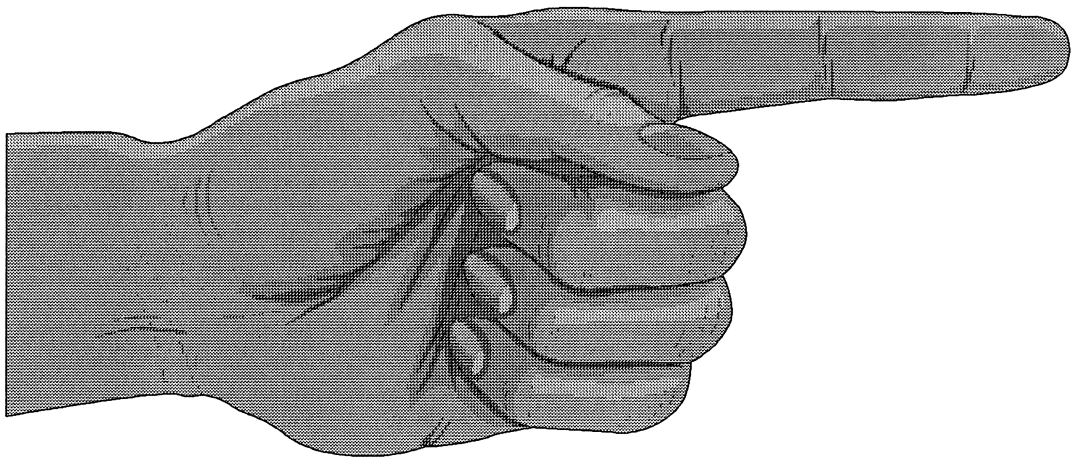
Solution by Aggressive Space Mapping
Fine Frequency Sweep





Solution by Aggressive Space Mapping
Detail of the Passband with Fine Frequency Sweep





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