MICROWAVE CIRCUIT CAD,
INCLUDING EM OPTIMIZATION AND
MODELING OF ARBITRARY STRUCTURES

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OSA90/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

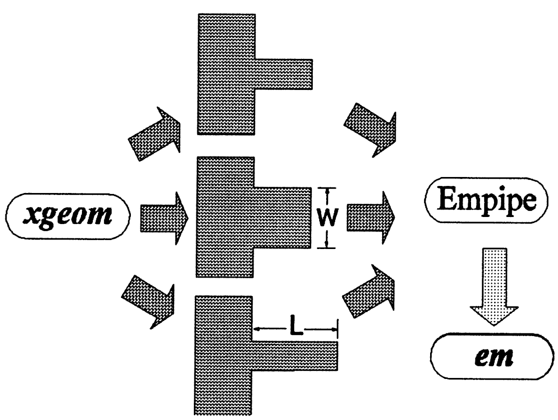
EmpipeExpress

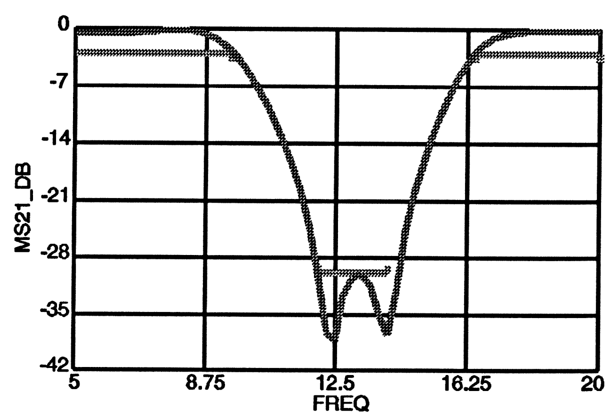
driving Sonnet's *em*

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

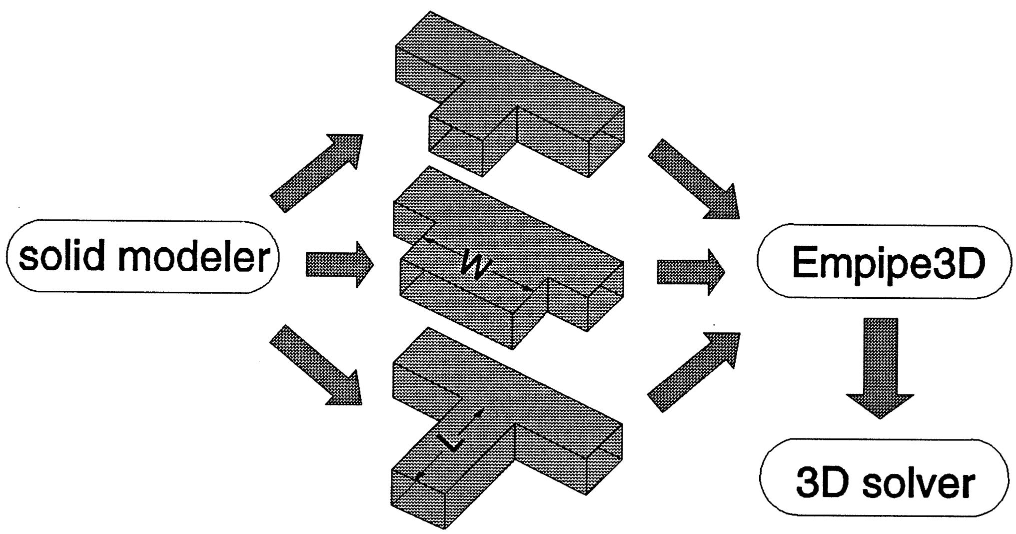
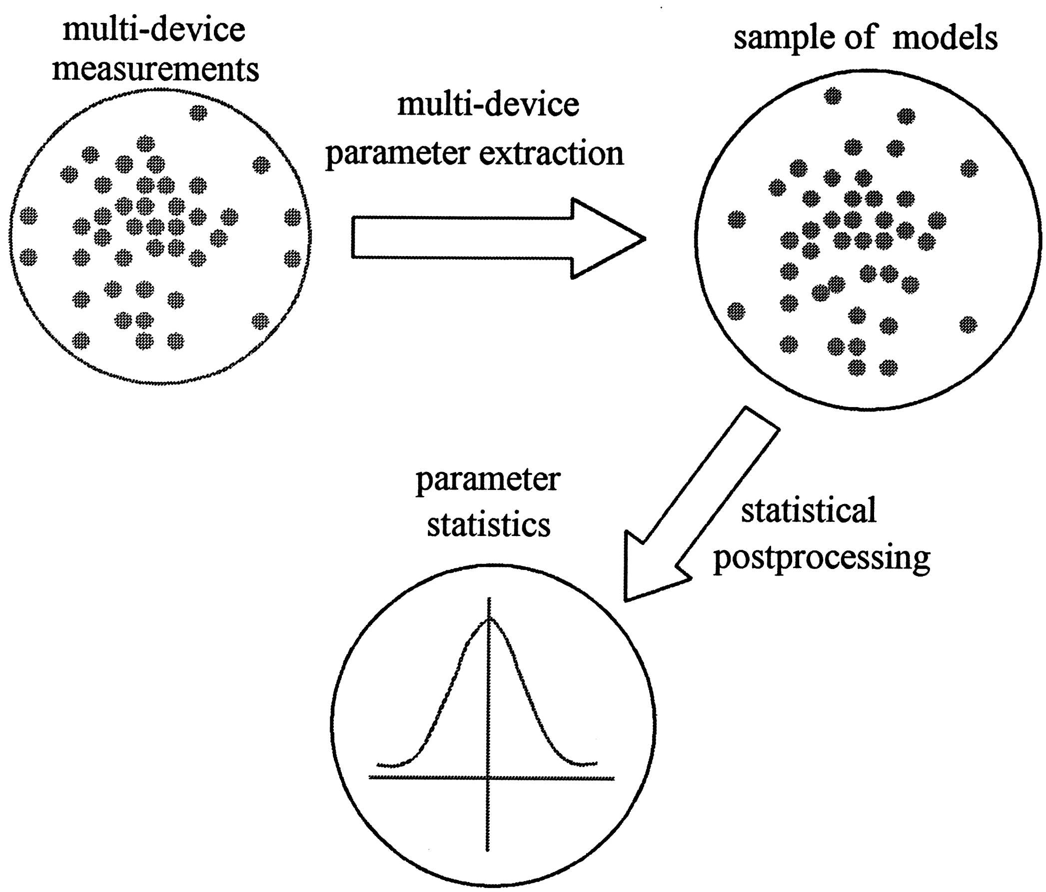
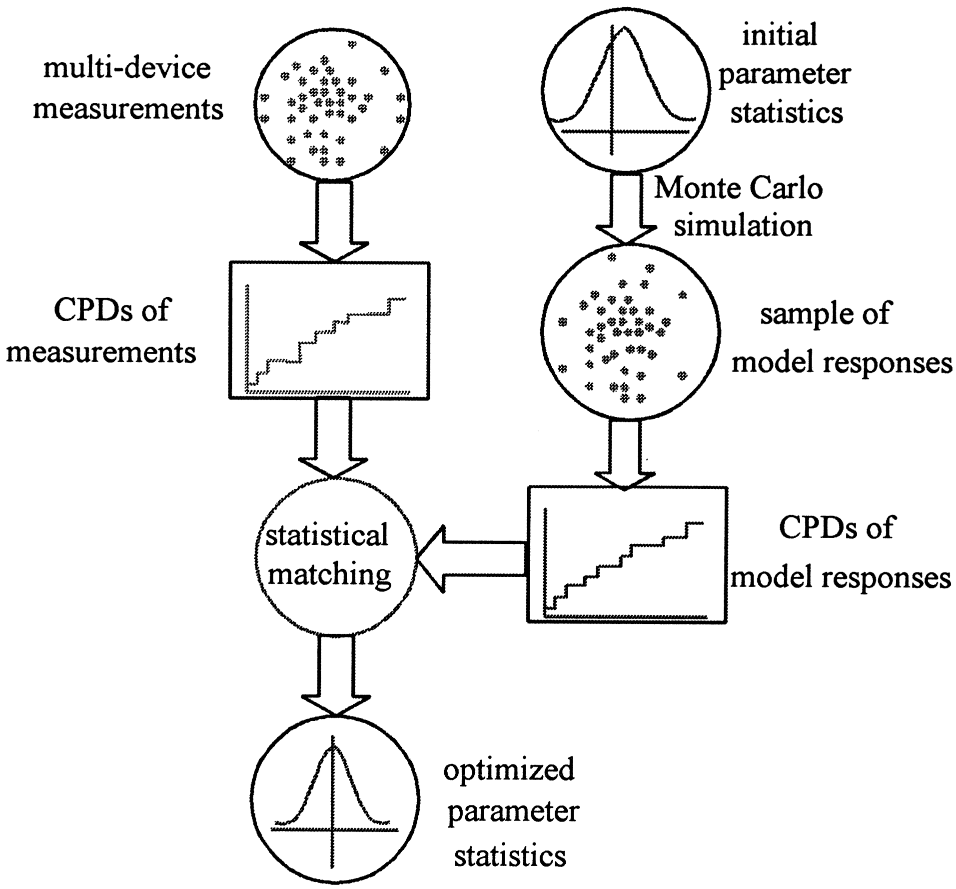


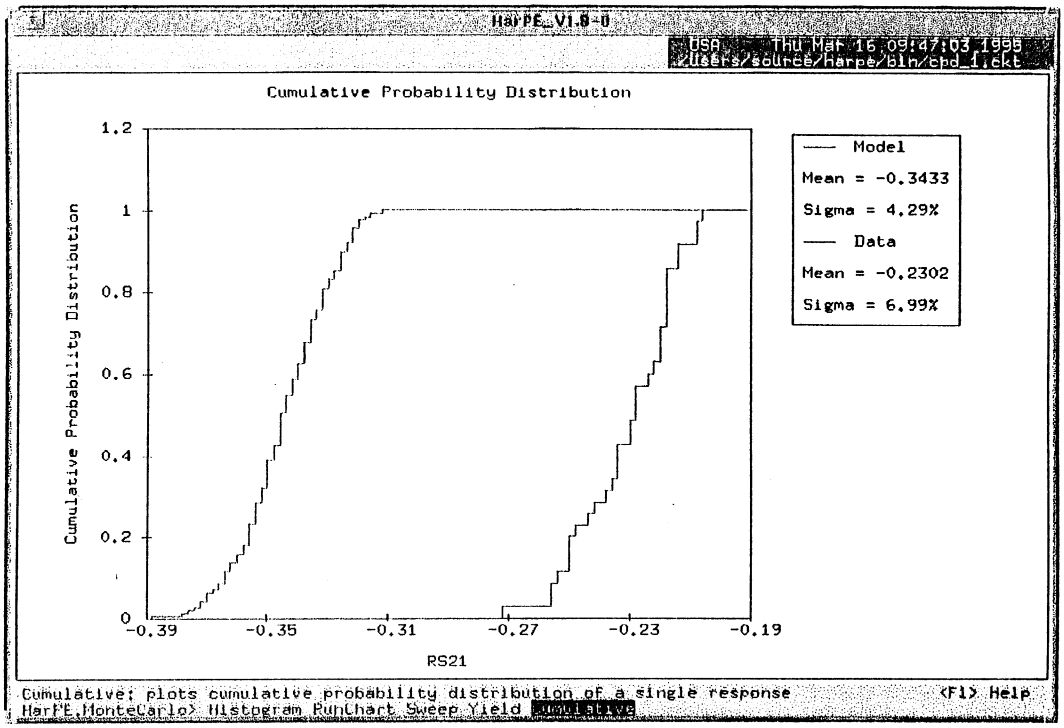
Illustration of Indirect Statistical Modeling

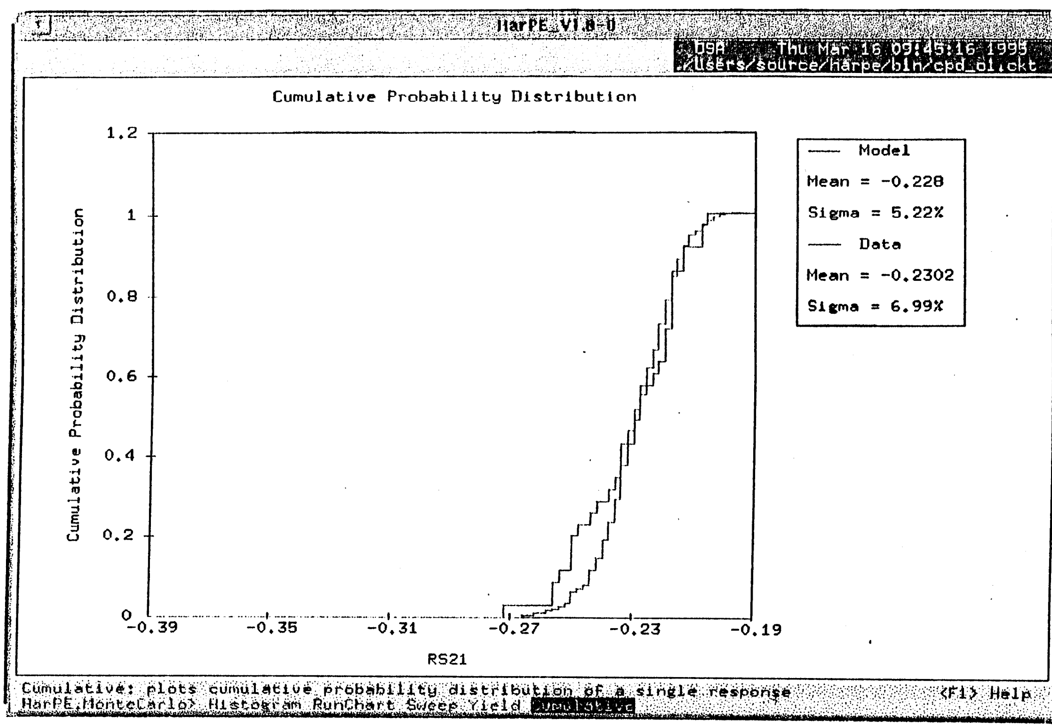


Direct Statistical Modeling Using CPD fitting

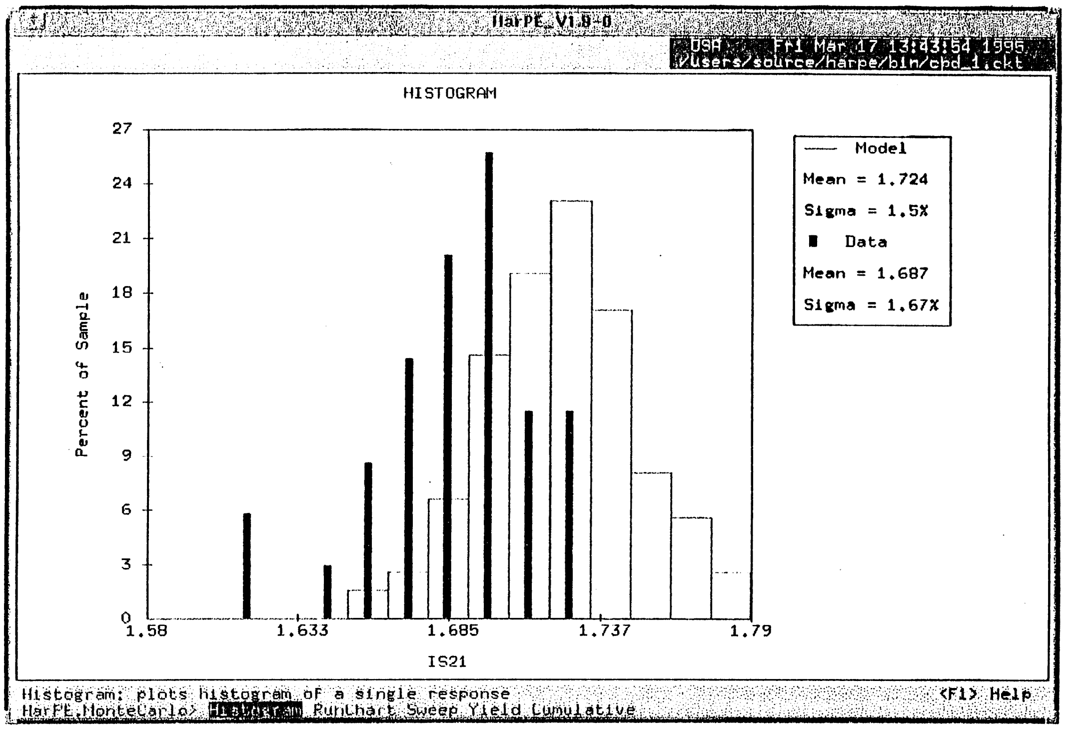


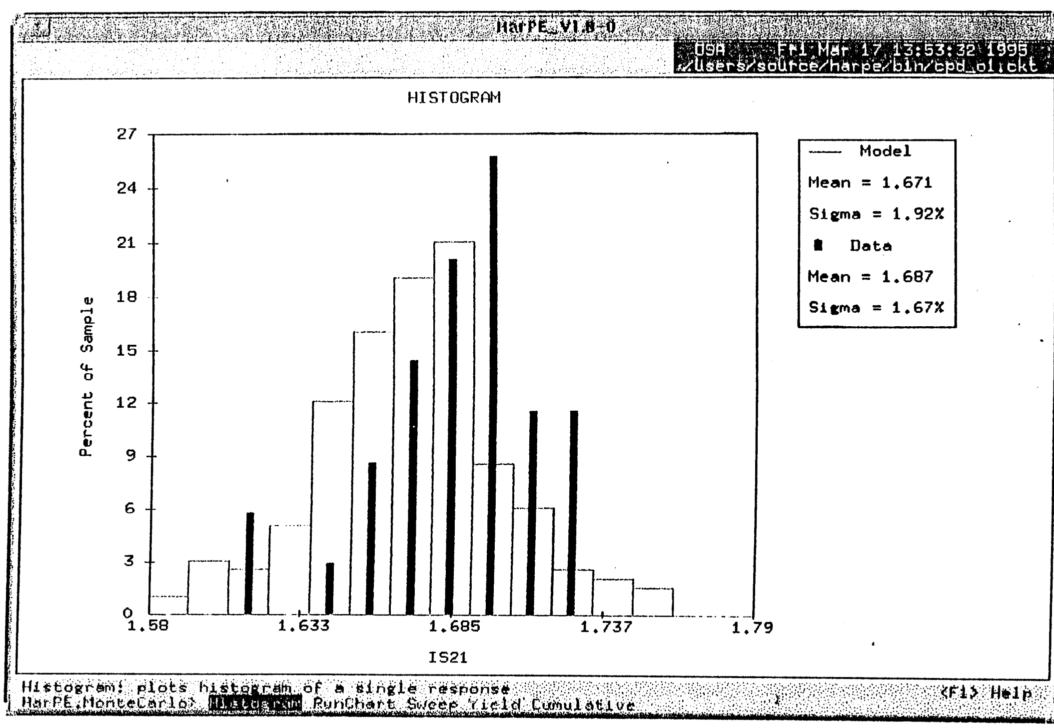
CPDs Before and After Optimization



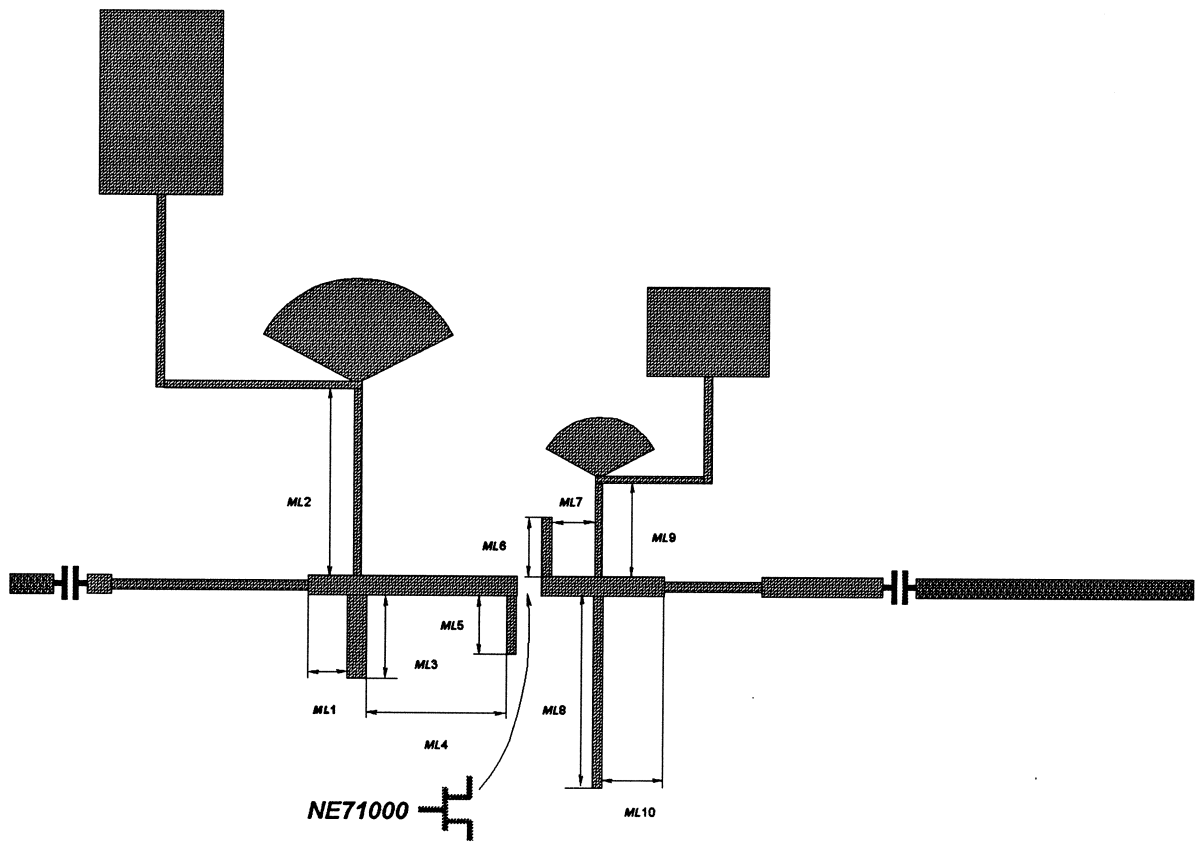


Histograms Before and After Optimization





Nonlinear FET Class B Frequency Doubler
(*Microwave Engineering Europe, 1994*)

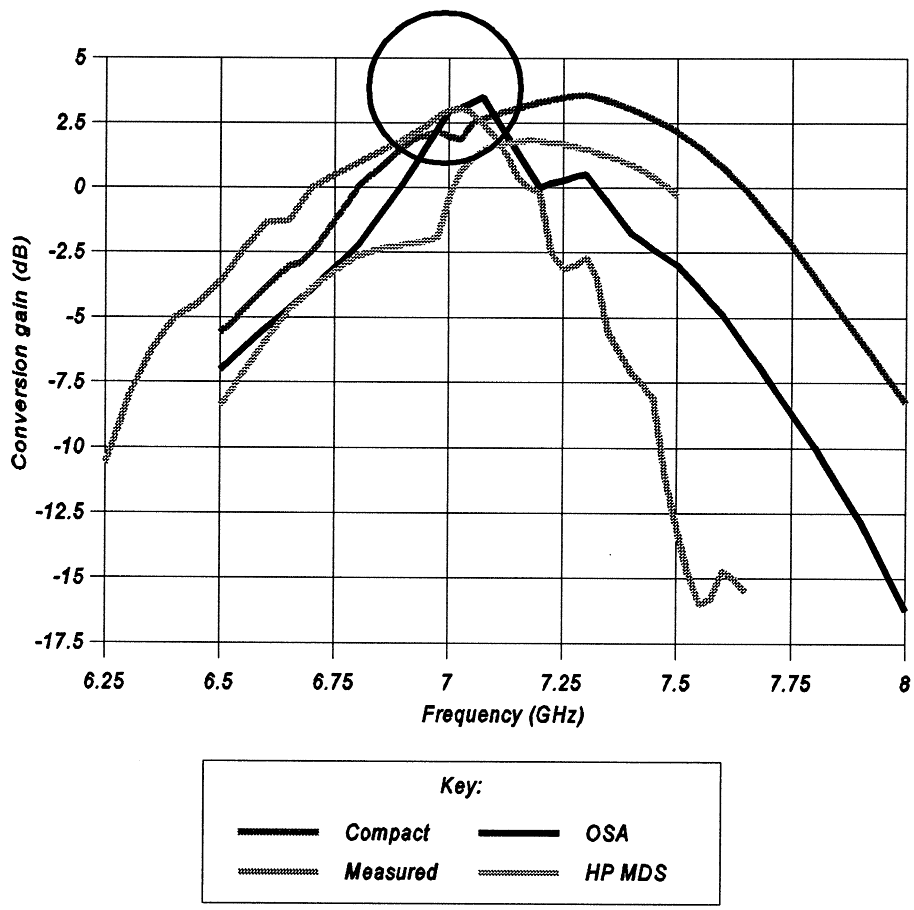


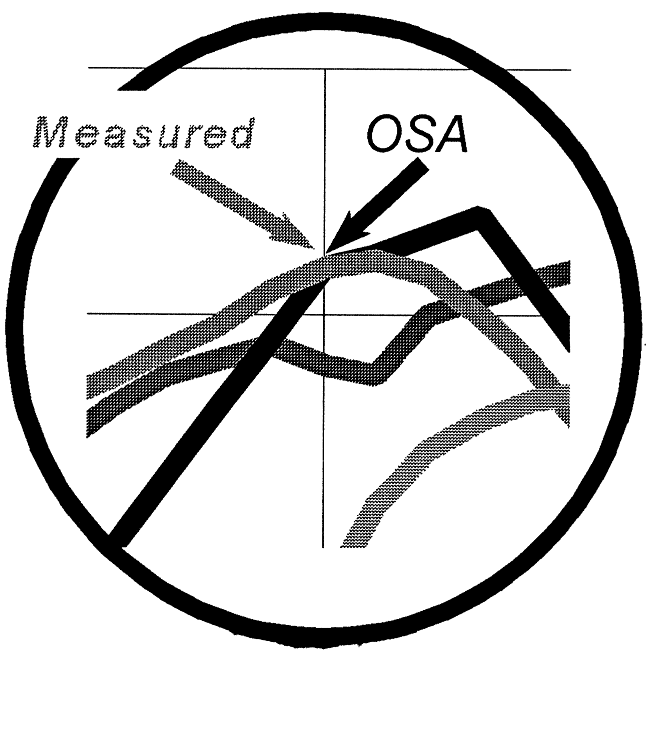
CAD benchmark example

a single FET (NE71000) and a number of microstrip elements including two radial stubs and two large bias pads

significant couplings between the microstrip elements

Comparison of Simulated and Measured results



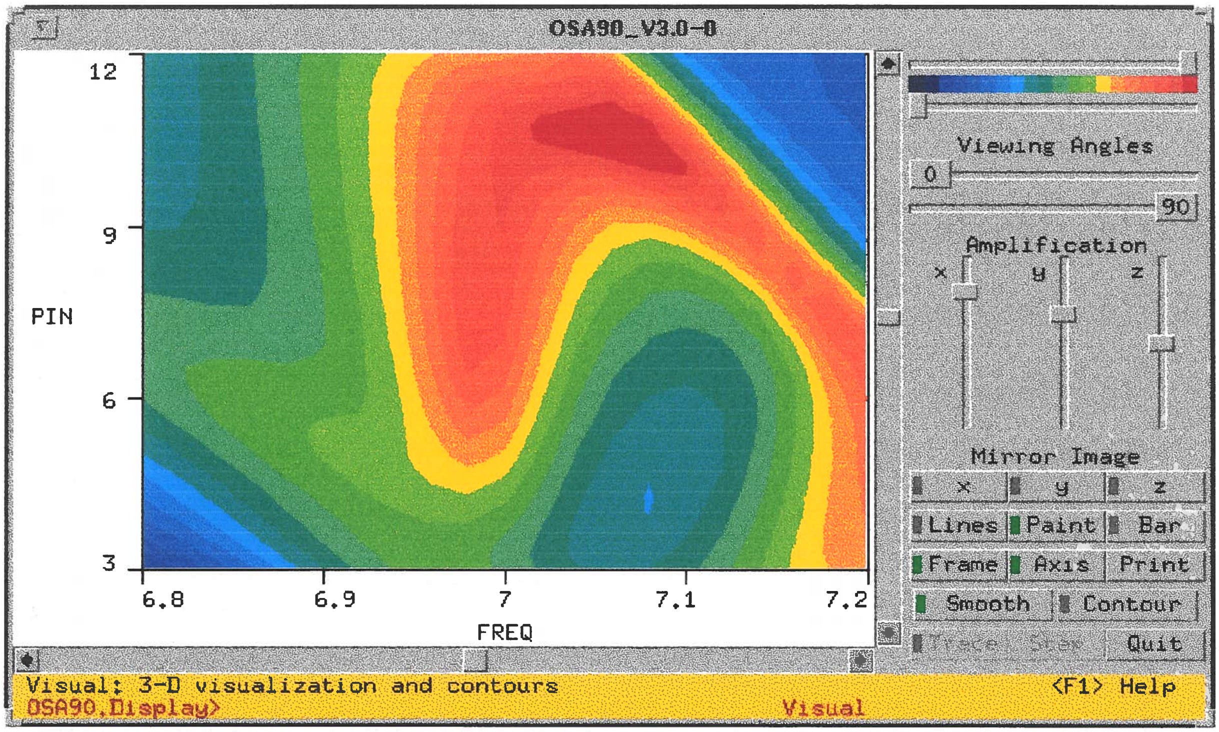


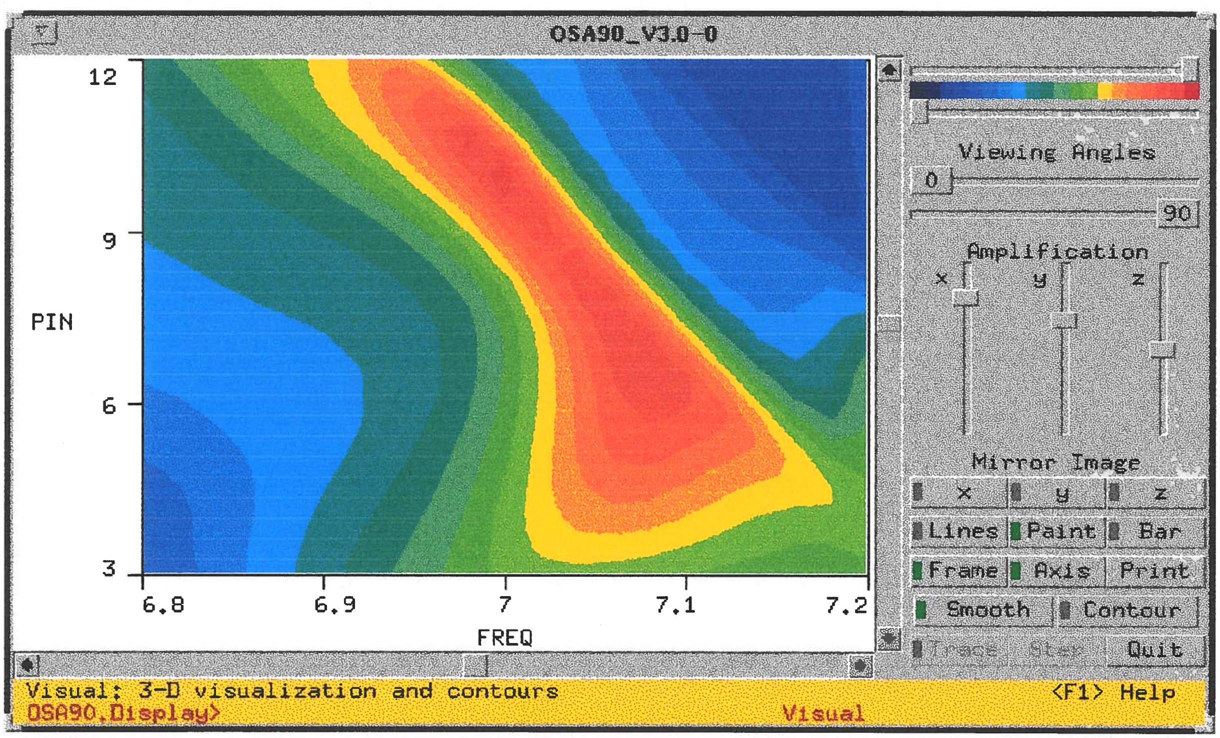
Detail around 7 GHz

The benchmark circuit is a 7 GHz frequency doubler

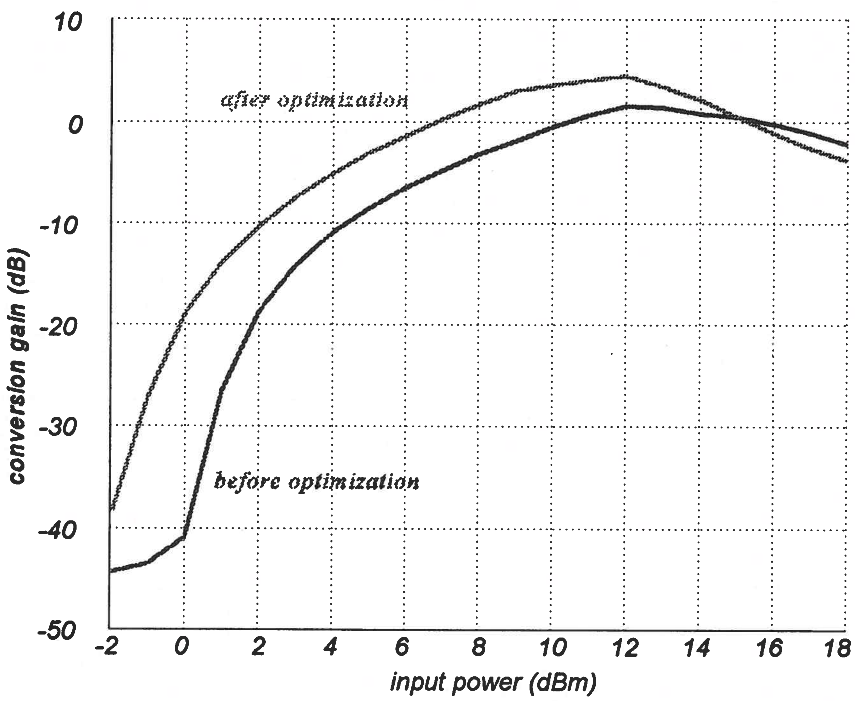
Microwave Engineering Europe, May 1994

Spectral Purity Before and After Optimization

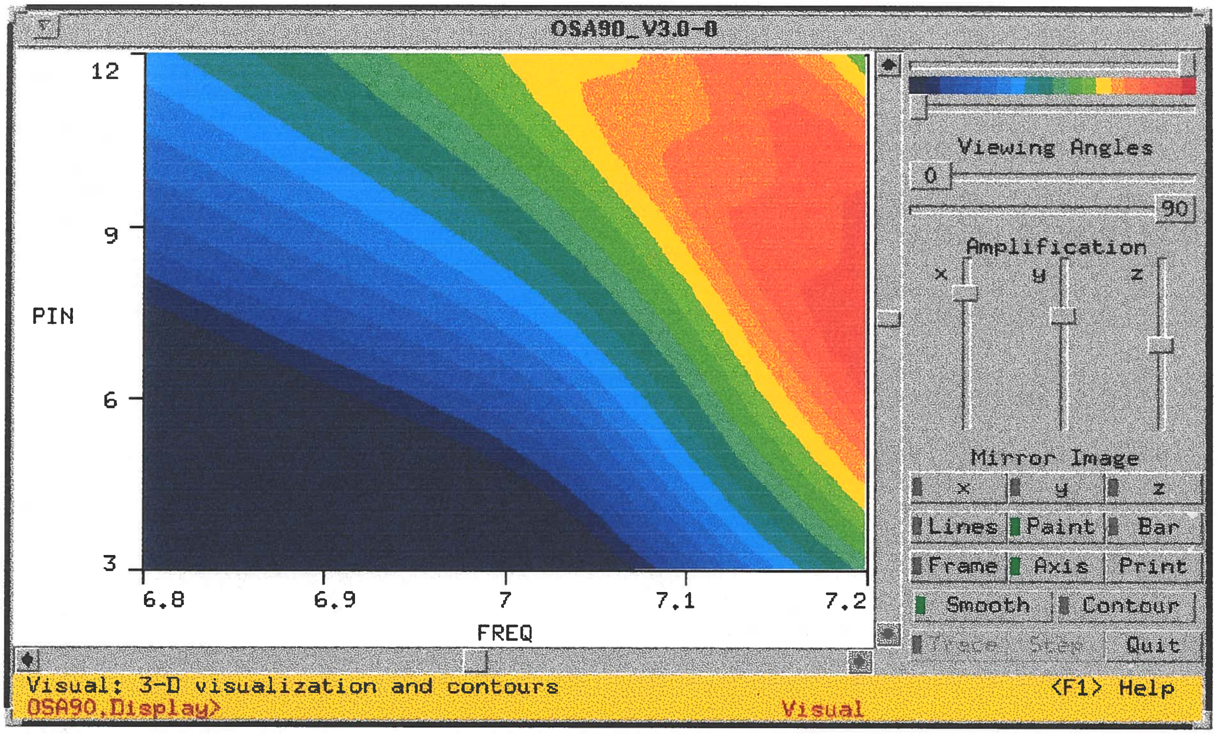


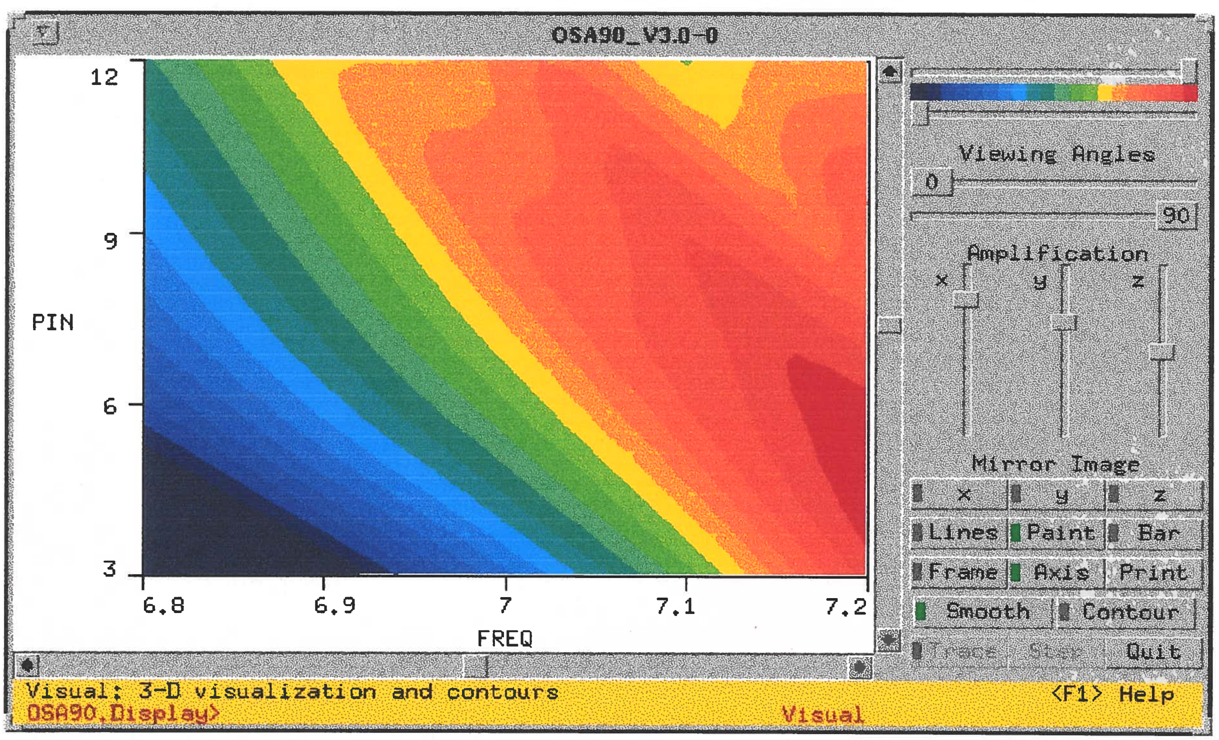


Conversion Gain Before and After Optimization



3D View of Conversion Gain Before and After Optimization





Critical Issues of Automated EM Optimization

interfaces between gradient-based optimizers and discretized EM field solvers: interpolation and database

integration of EM analysis with circuit simulation, including harmonic balance simulation of nonlinear circuits

Geometry Capture™: user-defined optimizable structures of arbitrary geometry

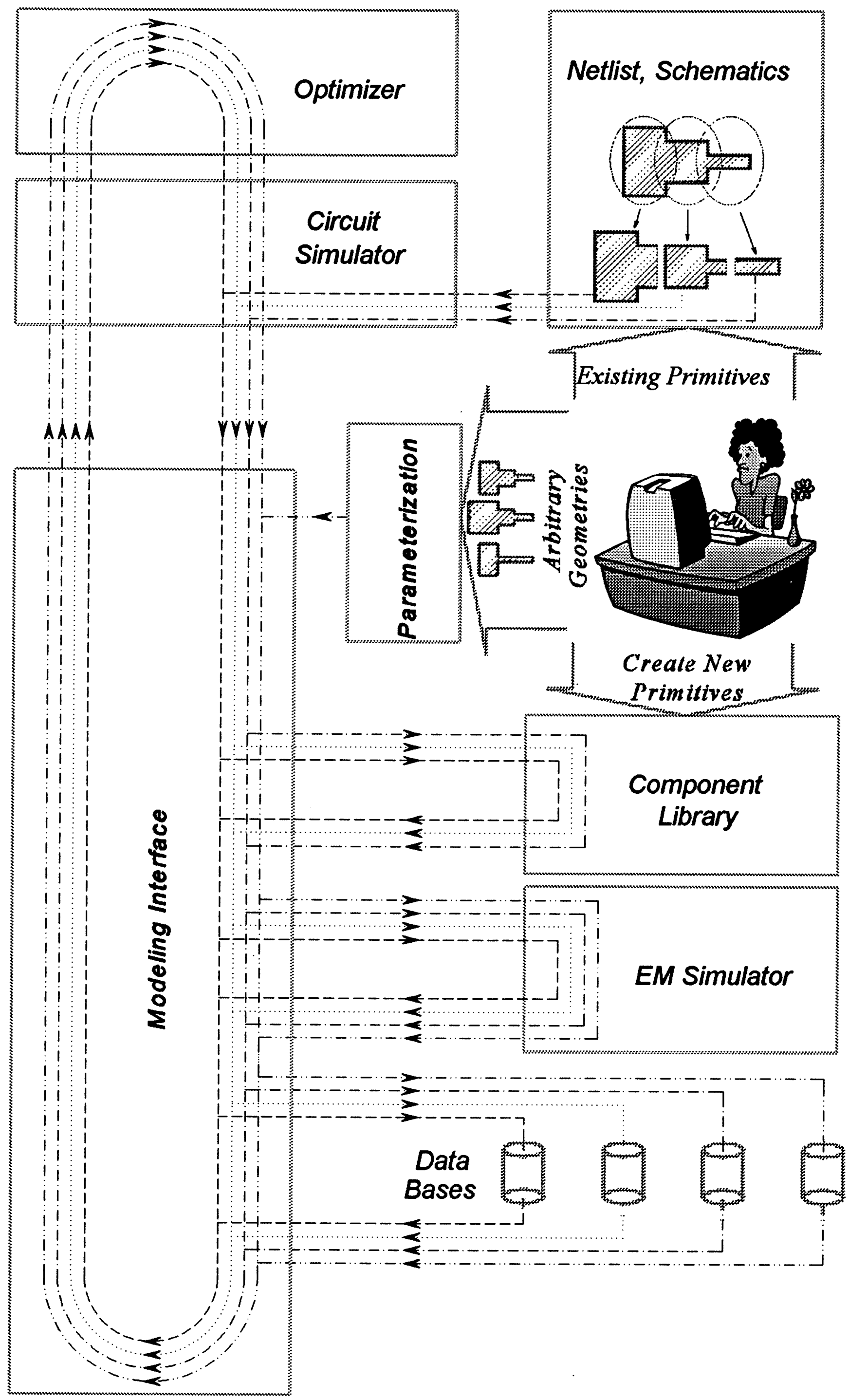
Space Mapping™ optimization: intelligent correlation between engineering models: EM models, empirical models and equivalent circuit models

smoothness and continuity of response interpolation

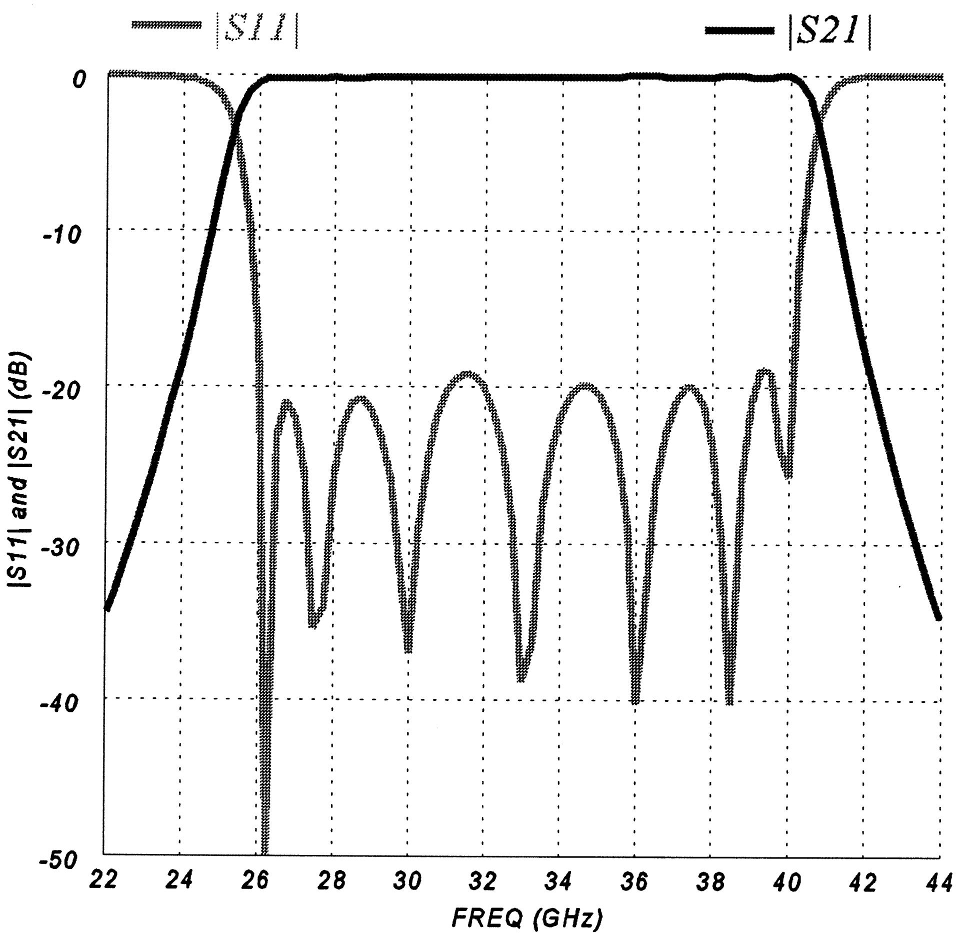
robustness of optimization algorithms and uniqueness of the solutions

parallel and massively parallel EM analyses

EM Optimization Environment



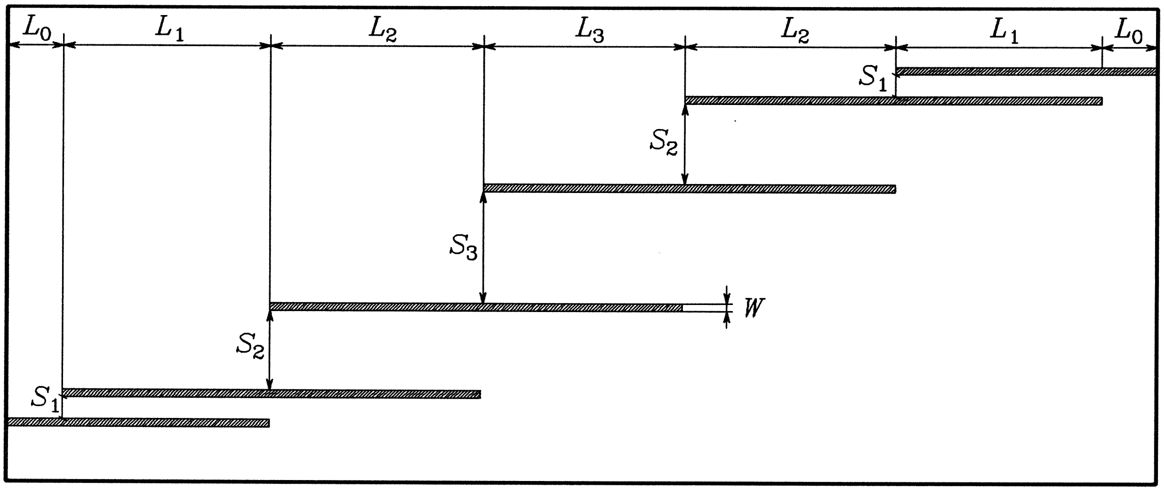
Simulation of the Interdigital Bandpass Filter After Optimization



a typical minimax equal-ripple response of the filter was achieved after a series of consecutive optimizations with different subsets of optimization variables and frequency points

the resulting geometrical dimensions were rounded to 0.1 mil resolution

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

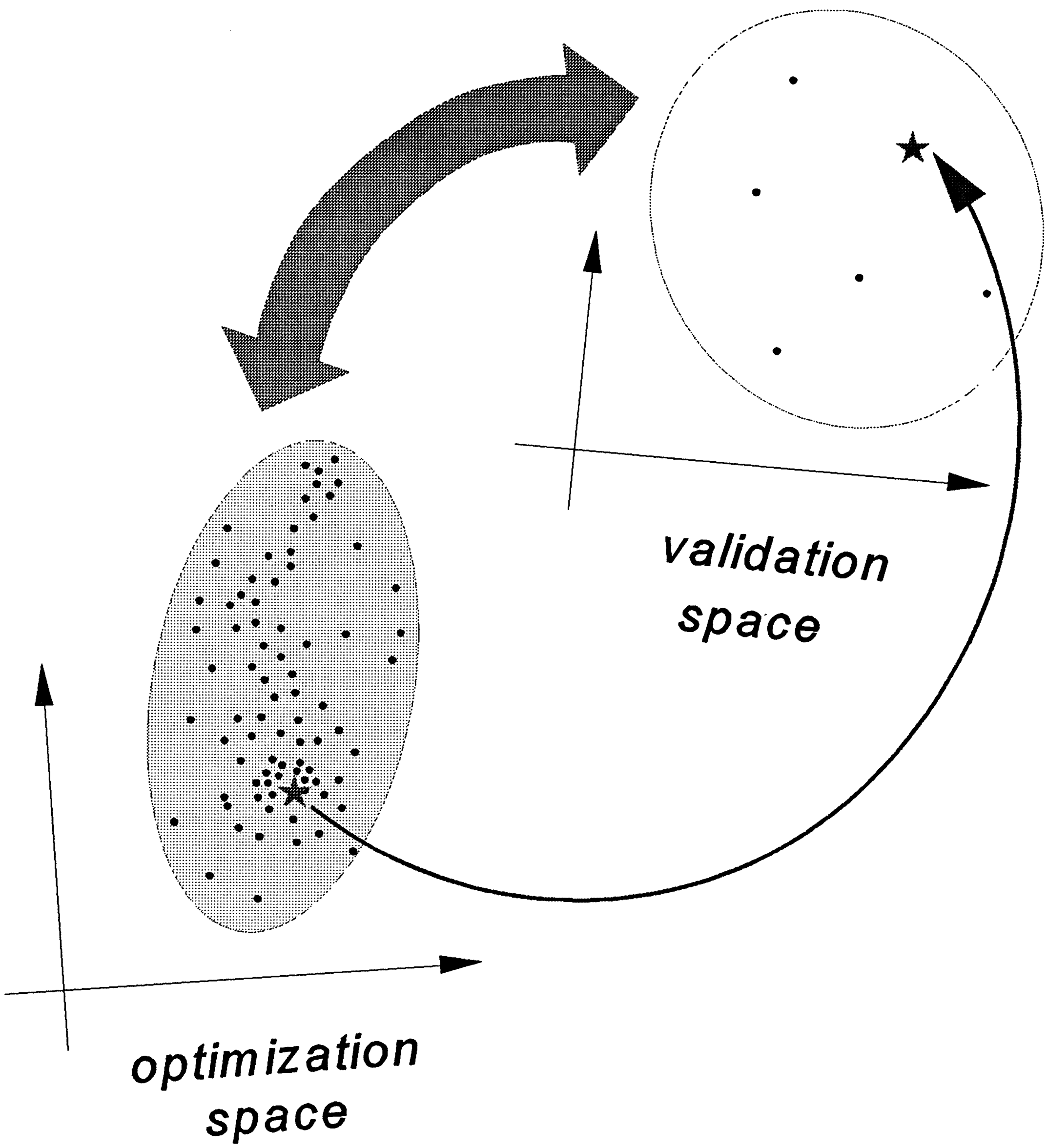
100 elapsed minutes are needed for ***em*** analysis at a single frequency on a Sun SPARCstation 10

design specifications

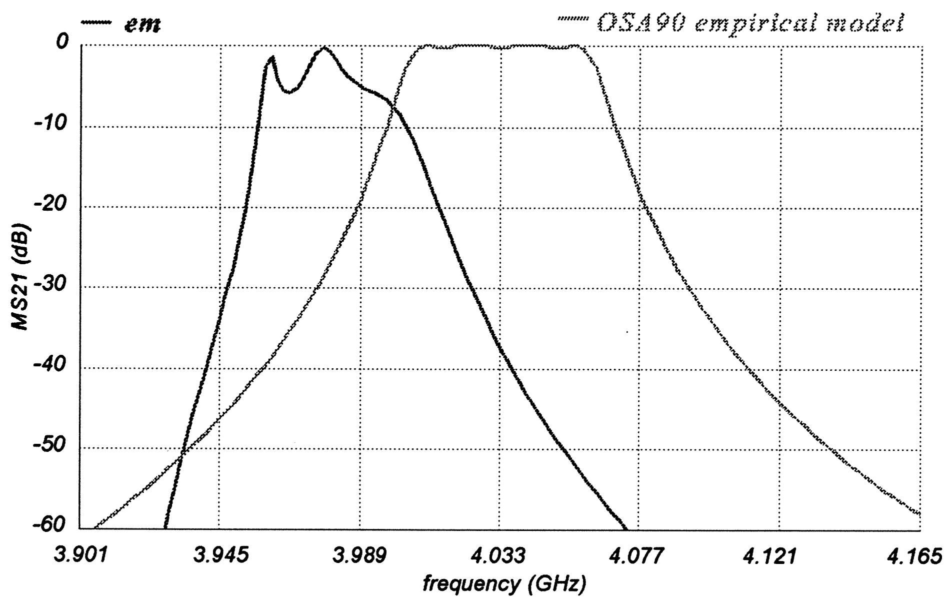
$S_{21} < 0.05$ for $f < 3.967$ GHz and $f > 4.099$ GHz

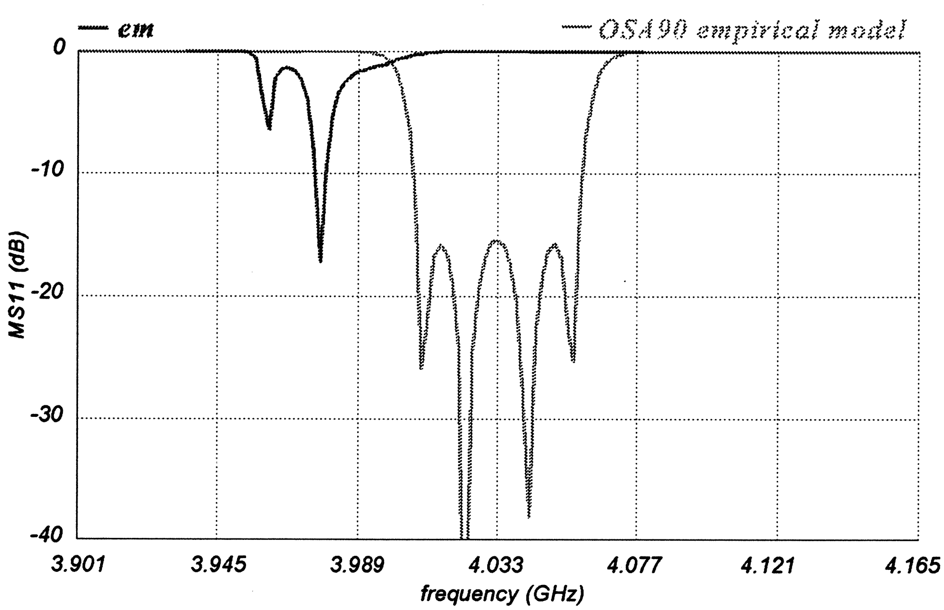
$S_{21} > 0.95$ for $4.008 \text{ GHz} < f < 4.058$ GHz

Space Mapping™
(Bandler et al., 1994)

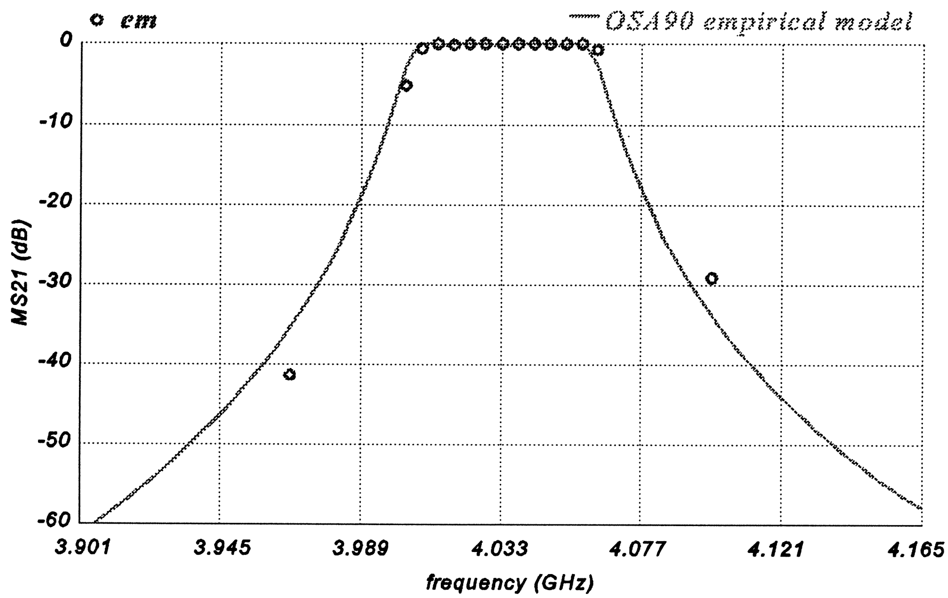


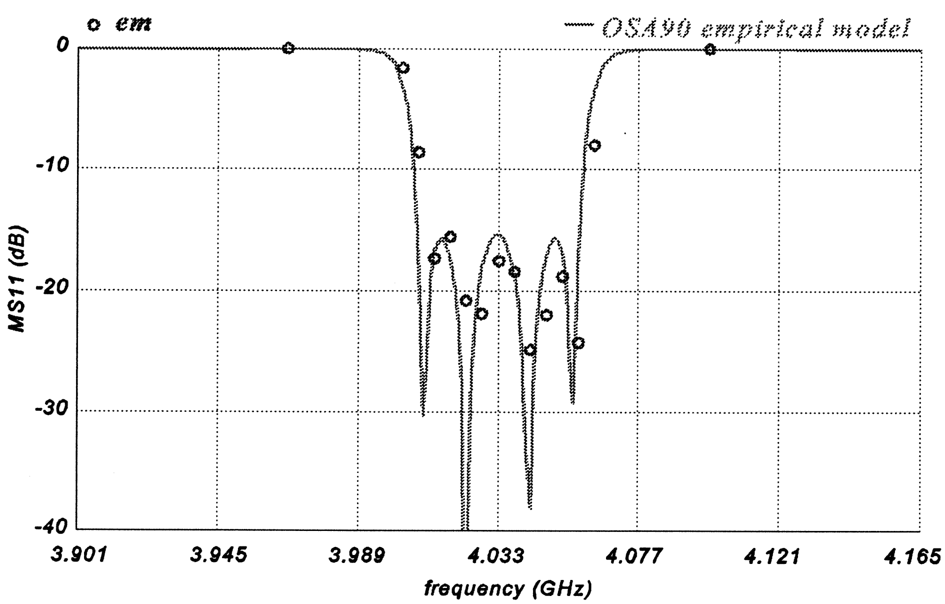
Starting Point of EM Optimization: Design Using Empirical Circuit Model



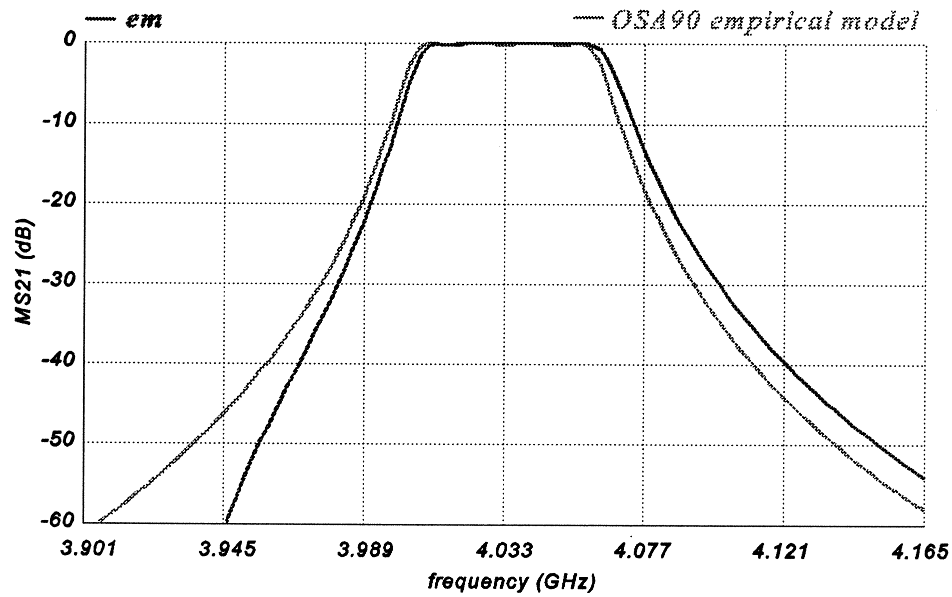


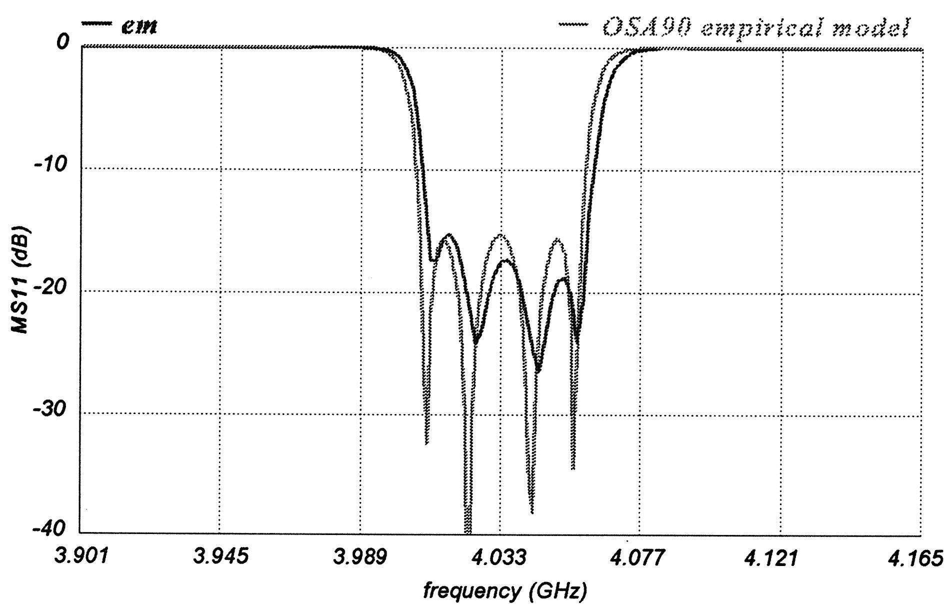
Solution by Aggressive Space Mapping After 3 Iterations



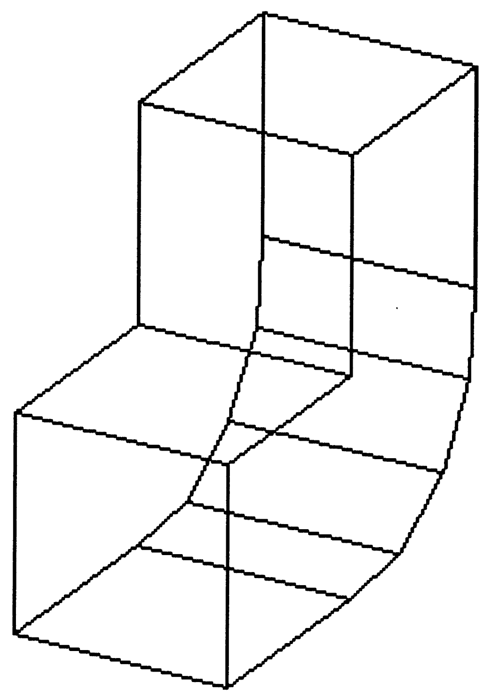


Solution by Aggressive Space Mapping
Fine Frequency Sweep

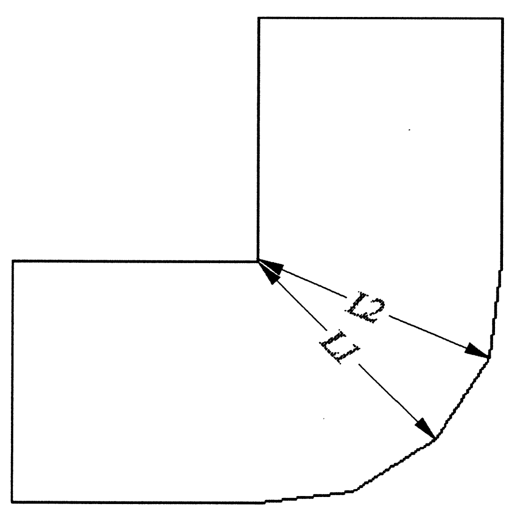




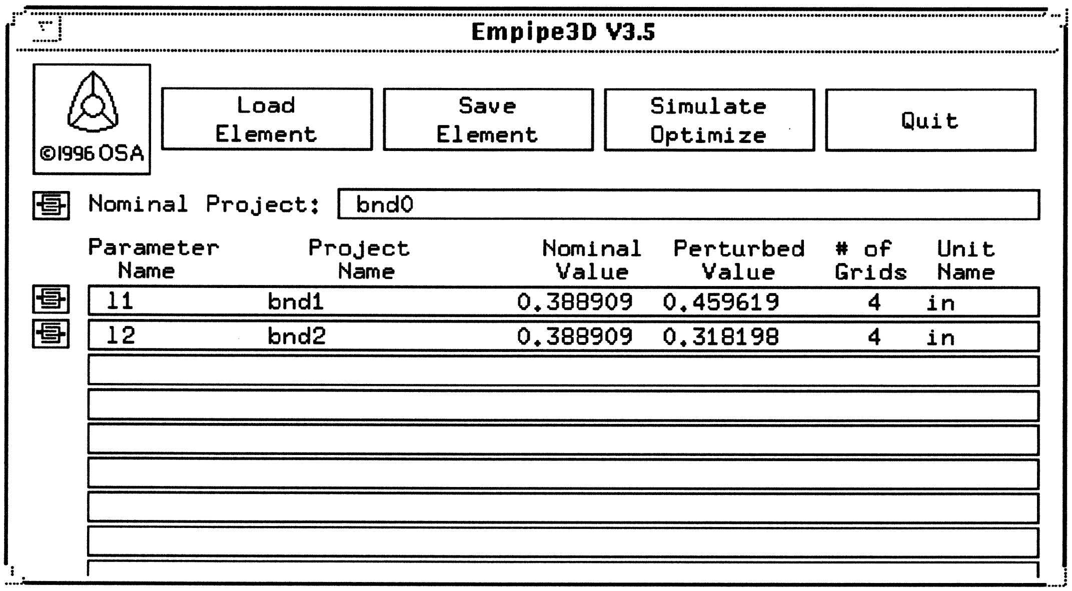
WR-75 Waveguide Bend
(only half of the structure is shown due to symmetry)



Two Design Variables

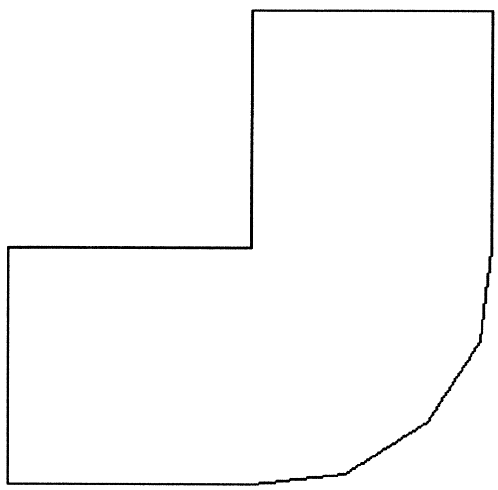


Empipe3D Geometry Capture

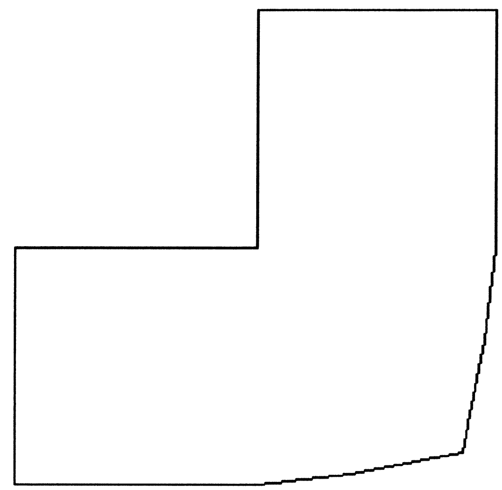


gateway to HFSS and Maxwell® Eminence

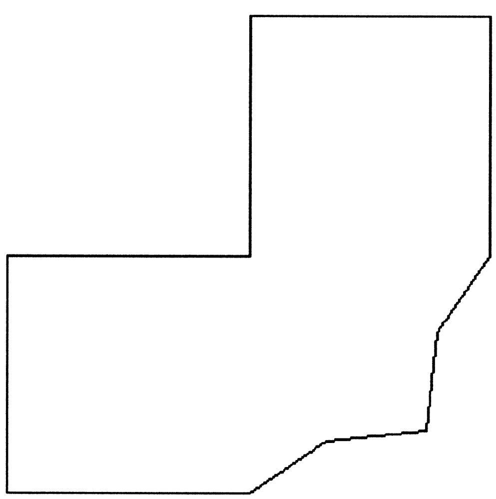
Geometries Representing the Parameters "L1" and "L2"



$L1$ = 0.3889 inch
$L2$ = 0.3889 inch

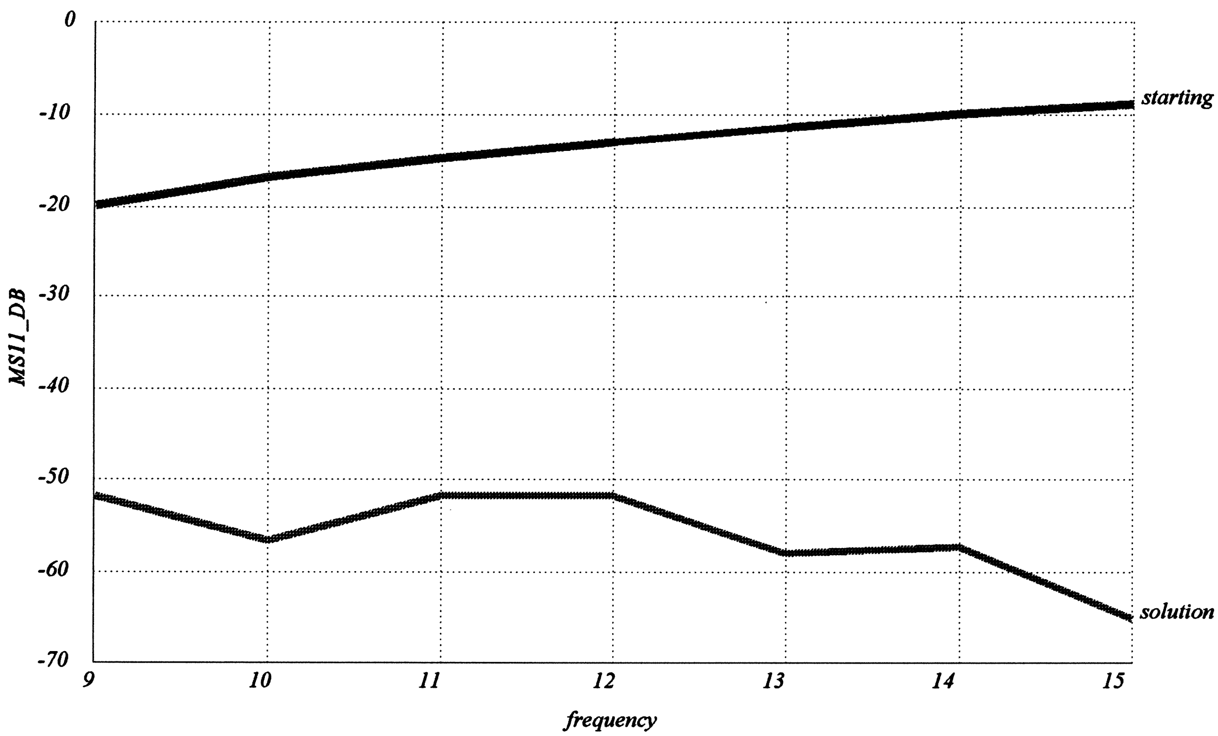


$L1$ = 0.4596 inch
$L2$ = 0.3889 inch



$L1$ = 0.3889 inch
$L2$ = 0.3182 inch

Automated Minimax Optimization



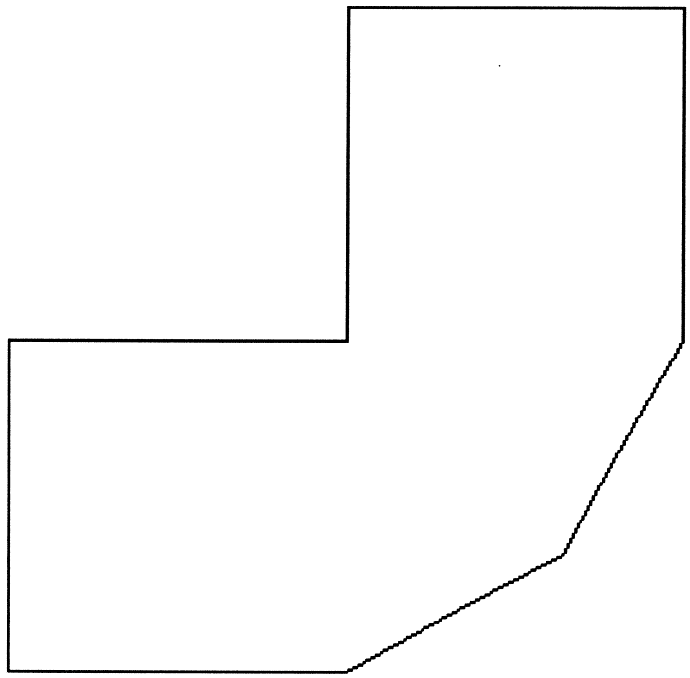
specification: return loss 40 dB from 9 to 15 GHz

starting point: *L1* = 0.3889 inch
L2 = 0.3889 inch

solution: *L1* = 0.343185 inch
L2 = 0.330018 inch

12 minimax iterations, 18 simulations by Maxwell Eminence

The Optimized Bend



this solution is virtually identical to the two-face bend optimized solution