WAVEGUIDE BEND OPTIMIZATION USING Empipe3D

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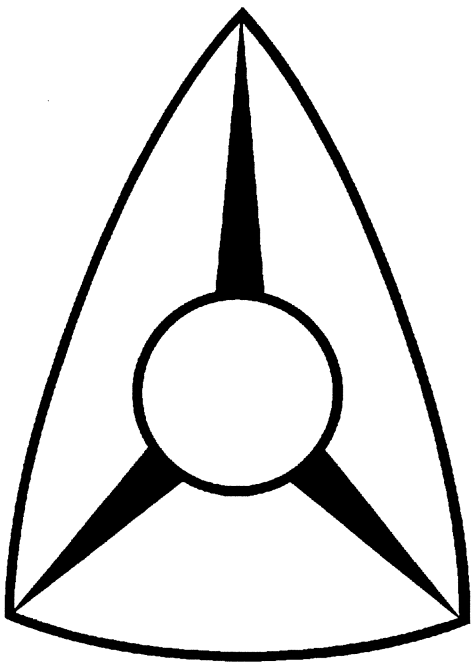
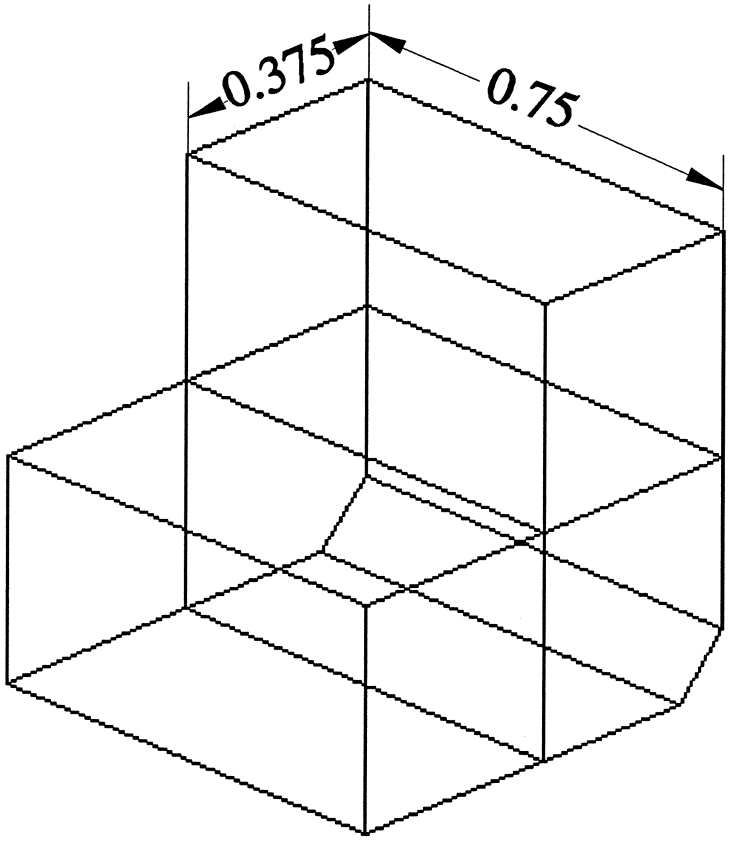
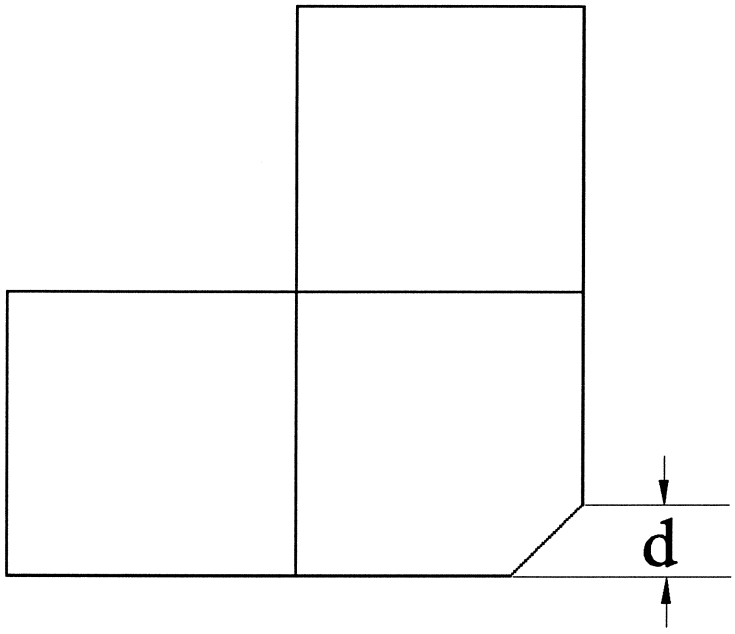


WR-75 Mitered Waveguide Bend

(*L.W. Hendrick, Hughes*)



Single Section Mitered Bend



specification in the frequency range from 9.84 to 15 GHz

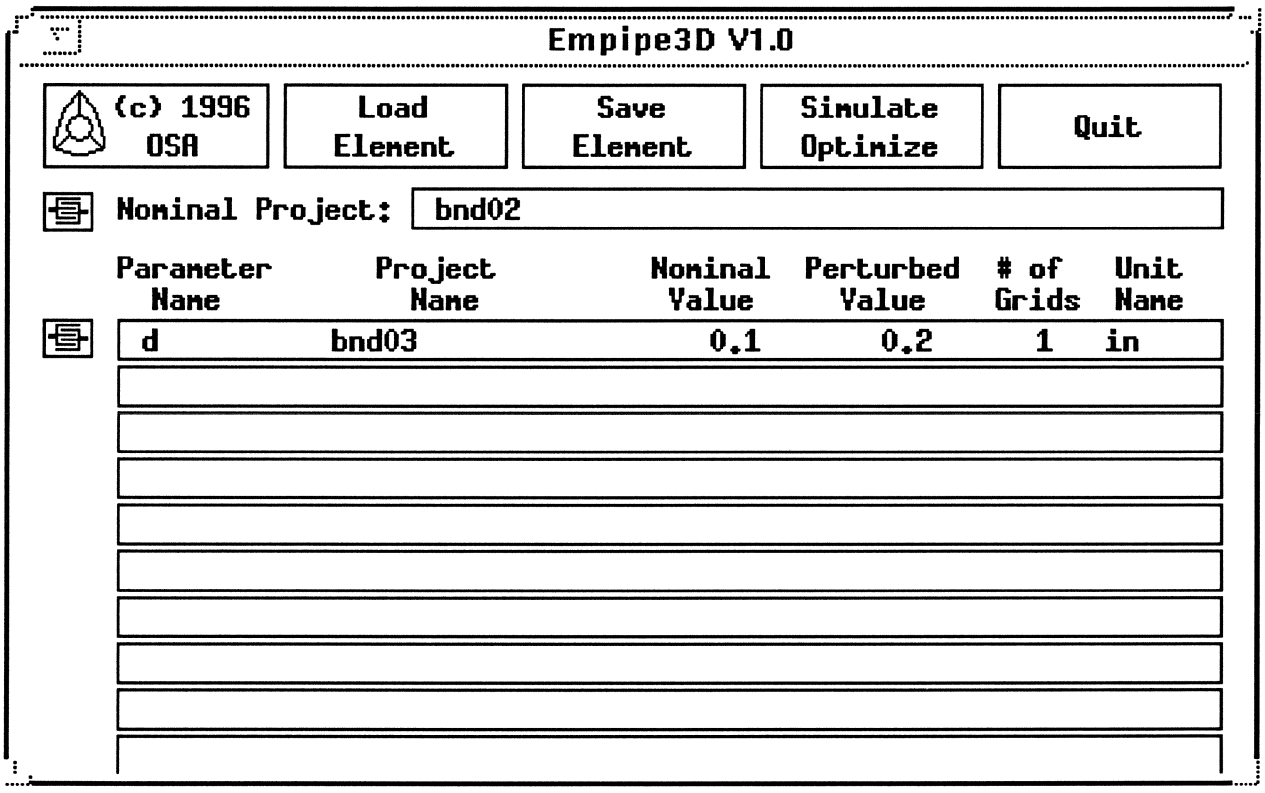
return loss ≥ 40 dB

one variable only: the position of the miter *d*, bounded as

$0 \leq d \leq 0.375$ inch

"can be done by hand in one or two days" (*L.W. Hendrick, Hughes*)

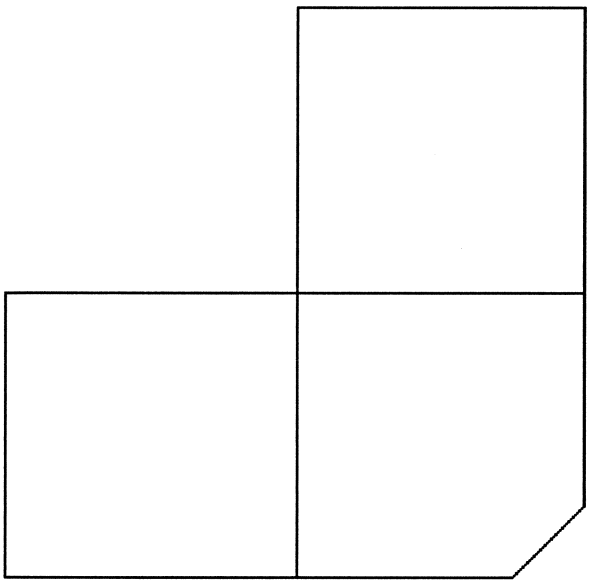
Empipe3D Geometry Capture



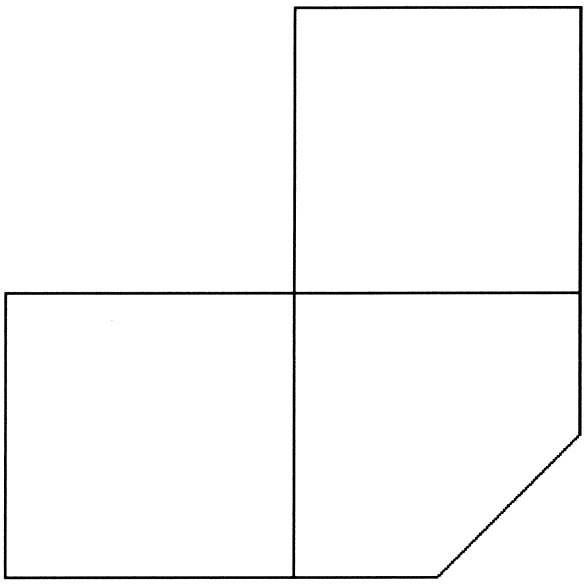
bnd02.pjt and bnd03.pjt are HFSS project directories

for n parameters, we need to create $n + 1$ projects

Geometries Representing the Parameter "d"



$d = 0.1$ inch



$d = 0.2$ inch

Essential Project Files for Empipe3D

project.db	material property database
project.sld	geometry description (solids)
project.sat	port, boundary and frequency definitions
project.svl	solution output mapping

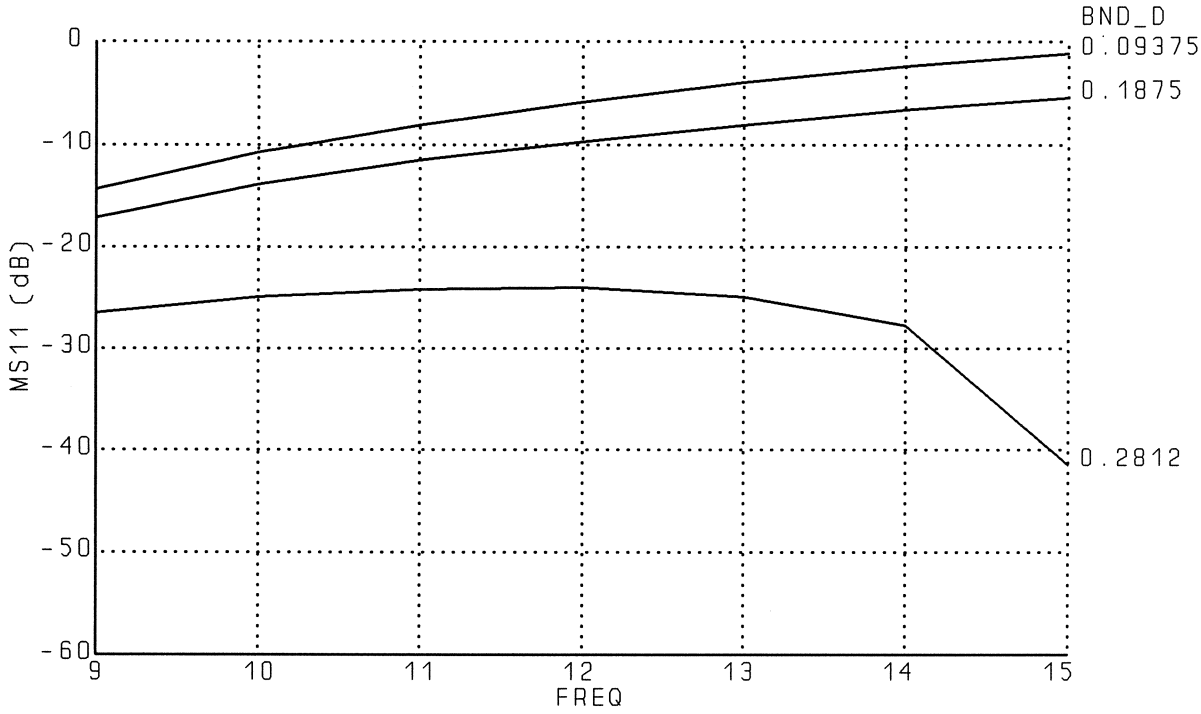
for the mitered waveguide bend, *project*.sld is the only file dependent on the parameter *d*

if the port or boundary positions are perturbed by changes in parameter values, then the *project*.sat file is also affected

parameters related to metal and dielectric characteristics will perturb the *project*.db file

the *project*.svl file is not affected by parameter perturbations in the Geometry Capture process

Sweep of the Miter Position



frequencies: from 9 GHz to 15 GHz with a step of 1 GHz

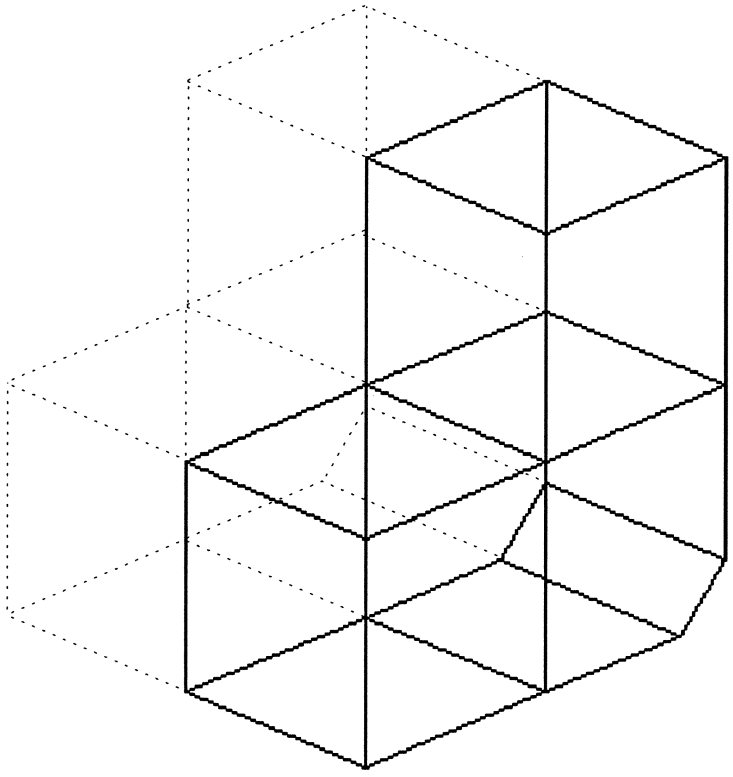
d is swept for 0.09375, 0.1875 and 0.28125 inch

simulation time is approximately 8 CPU hours for each value of *d* (SPARCstation 10, 9 adaptive meshing iterations)

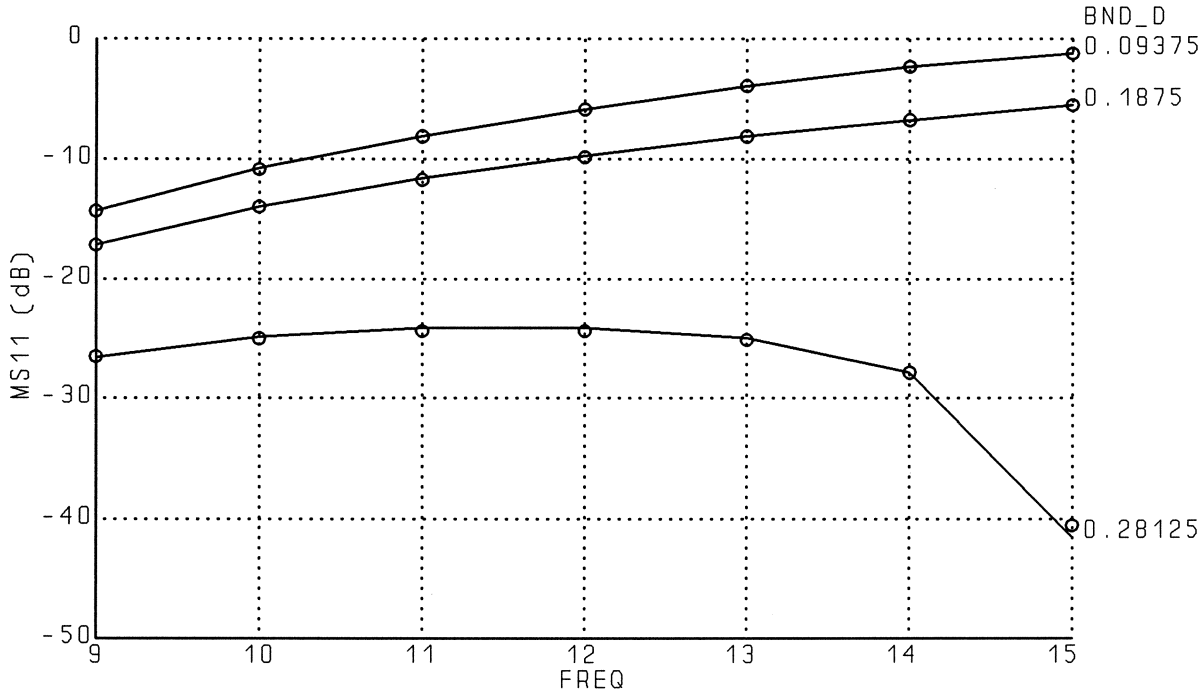
Geometric Symmetry of the Waveguide Bend

symmetry can be exploited to reduce the field solver computation time

for the waveguide bend, the use of a "Perfect H Boundary" allows HFSS to analyze only one half of the structure



Simulation Results with and without Using Symmetry

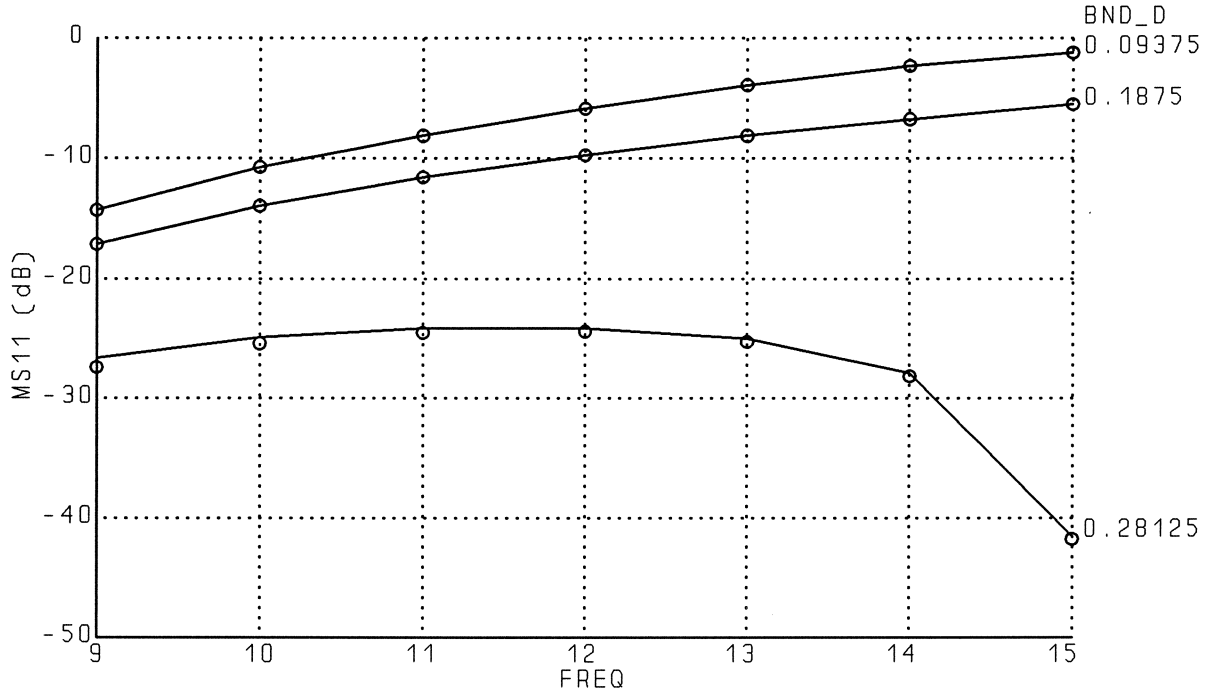


the lines depict responses by analyzing the whole structure

the circles depict responses by analyzing one half of the symmetrical structure

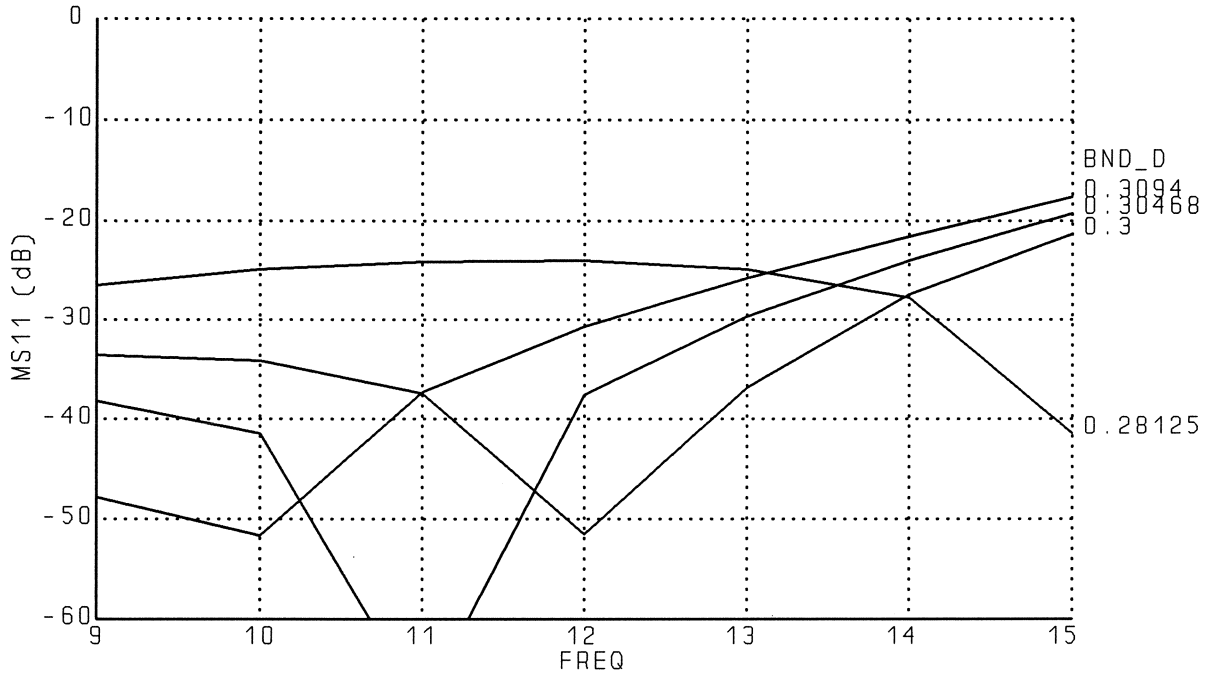
the ratio of CPU simulation times is approximately 3:1

Comparison of HFSS and Maxwell Eminence



the results by HFSS (lines) and Maxwell Eminence (circles) are practically identical

Fine Sweep of the Parameter "d"

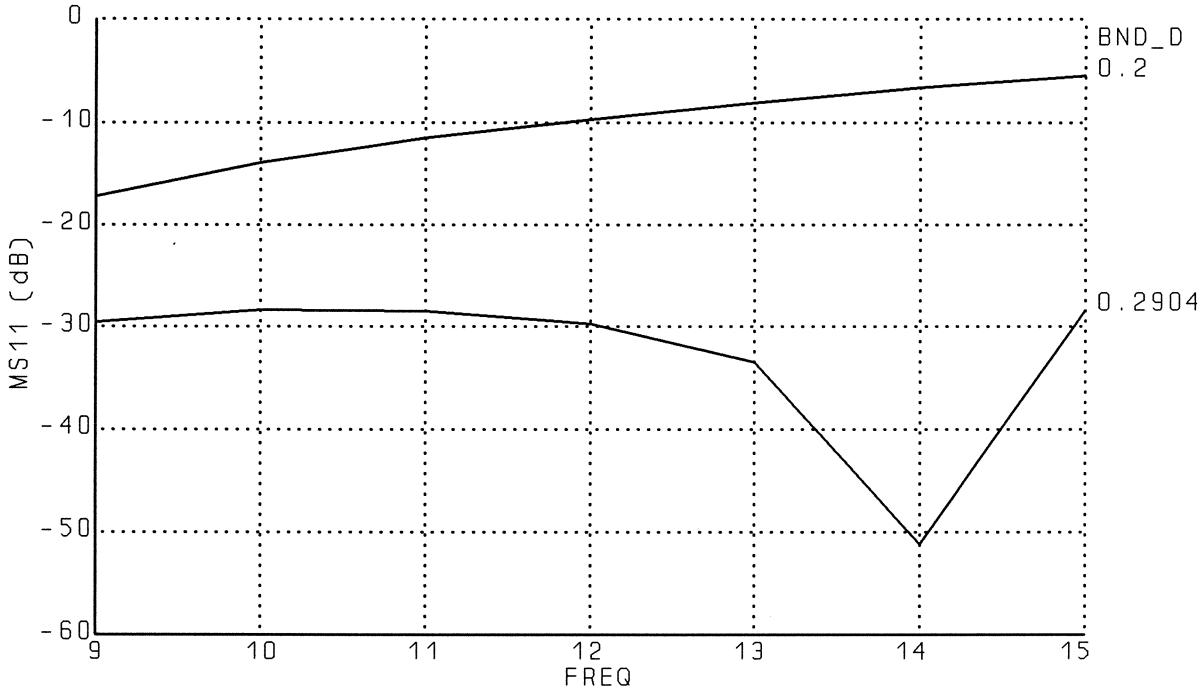


to emulate design by hand, we sweep *d* with these values: 0.28125, 0.3, 0.304675 and 0.3094 inch

by visual inspection, we can relate the position of the return loss pole to the parameter *d* as 1 GHz / 0.005 inch

design by hand would require 7 to 10 HFSS simulations (25 to 35 CPU hours on a SPARCstation 10)

Automated Minimax Optimization

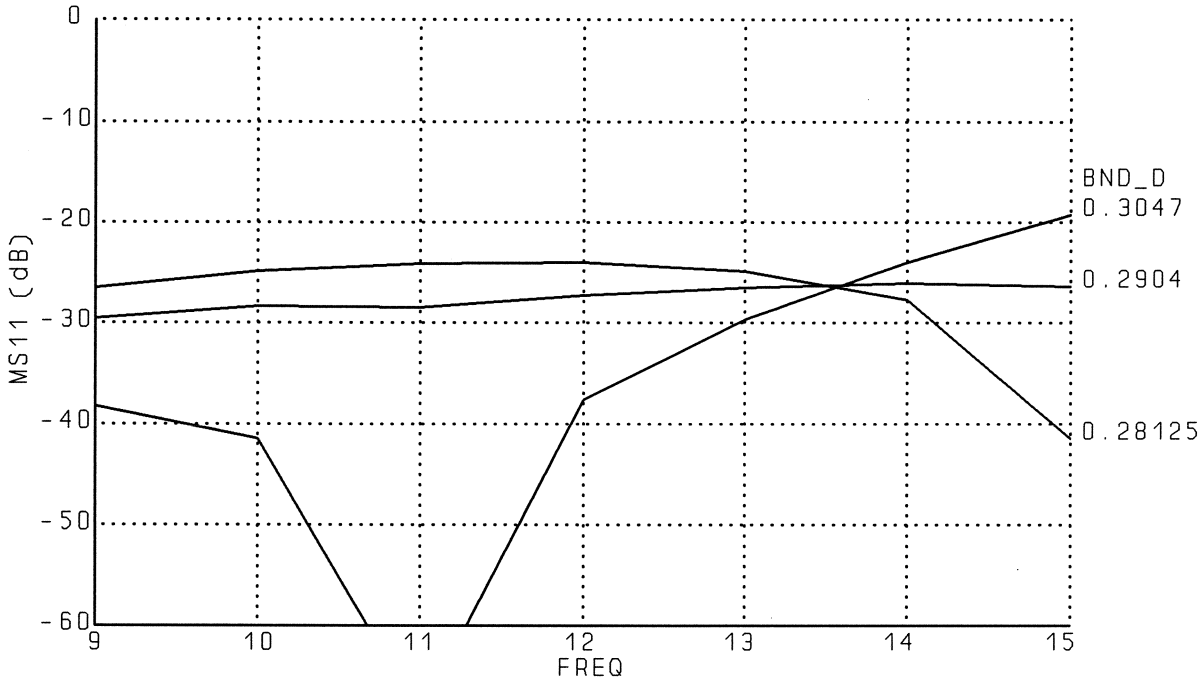


starting point: $d = 0.2$ inch
solution: $d = 0.2904$ inch

9 minimax iterations, 8 HFSS simulations (including gradient calculations, approx. 27 CPU hours on a SPARCstation 10)

d is discretized with a grid of 0.0234375 inch

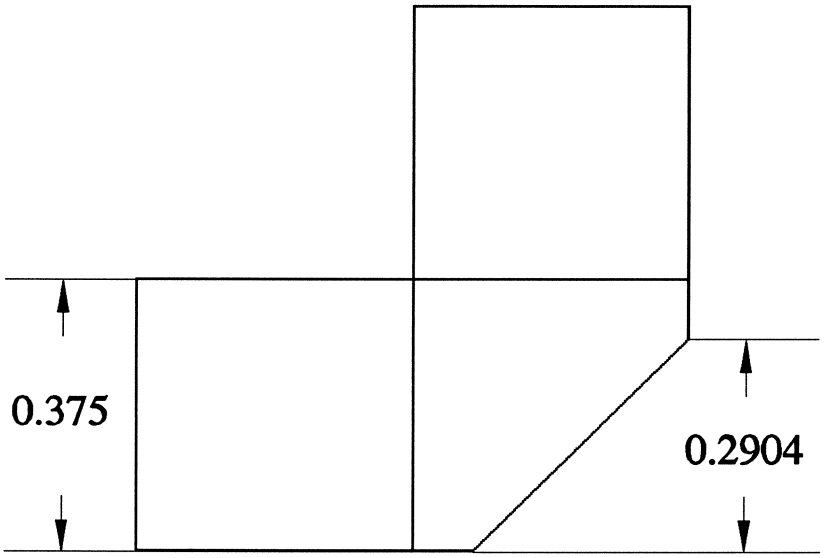
Problem with S-Parameter Interpolation



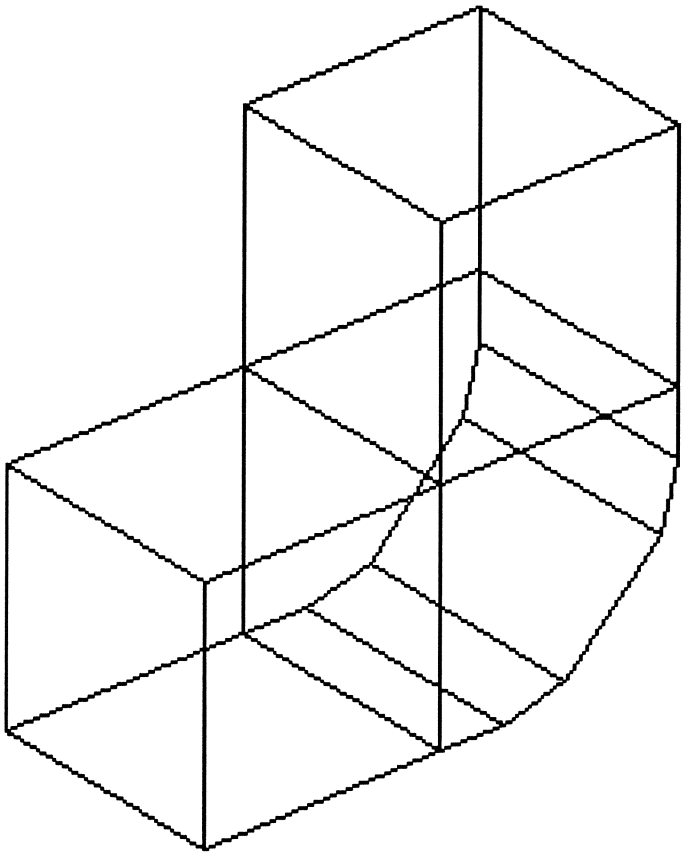
linear interpolation based on the magnitude and phase of the *S* parameters fails to preserve the notch

the problem is overcome using linear interpolation on the real and imaginary parts of the *S* parameters (by setting the Empipe3D parameter MODEL=7)

The Optimized Mitered Bend



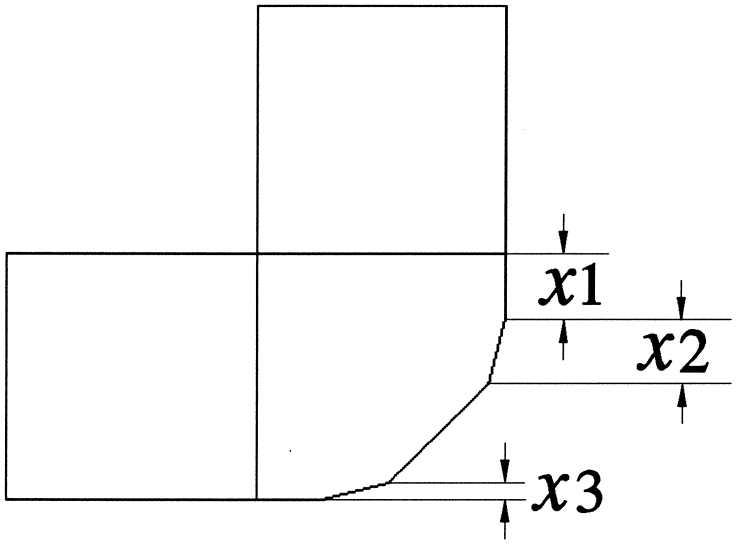
Three-Section Mitered Bend



"a three section can be designed by hand using HFSS in about three days" (*L.W. Hendrick, Hughes*)

"beyond three sections the problem exceeds what can be achieved practically by hand" (*L.W. Hendrick, Hughes*)

Parameters for the Three-Section Mitered Bend



caution: if the parameters are allowed to vary freely, they may "collide", resulting in unacceptable geometries

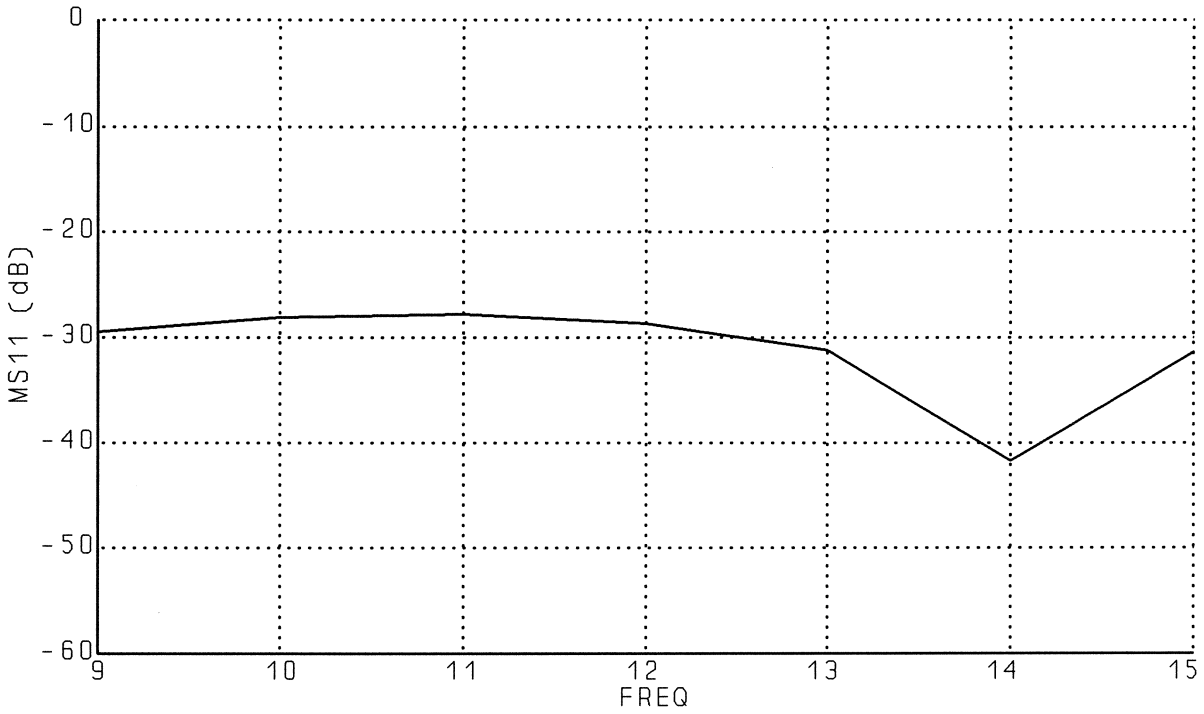
appropriate constraints:

$x1 > 0, \quad x2 > 0, \quad x3 > 0$

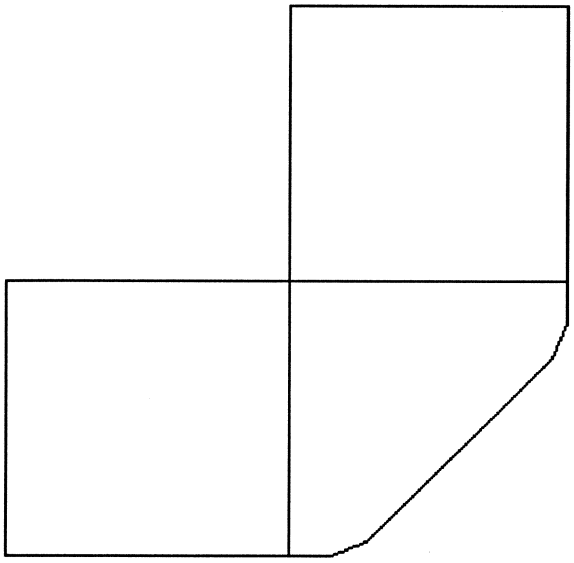
$x1 + x2 + x3 < 0.375$ inch

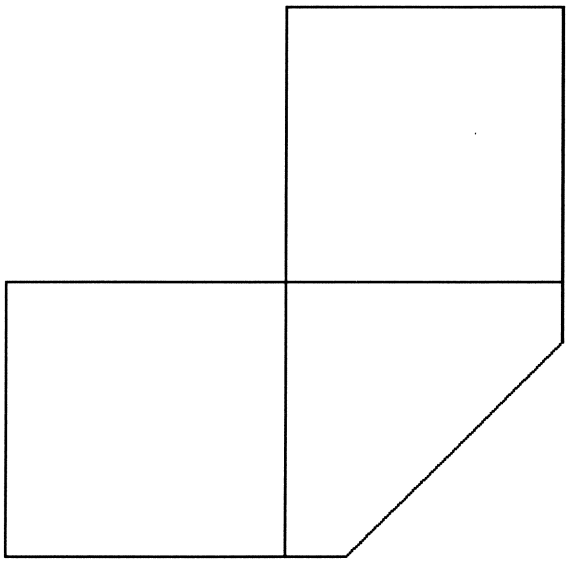
$x2 > x3$

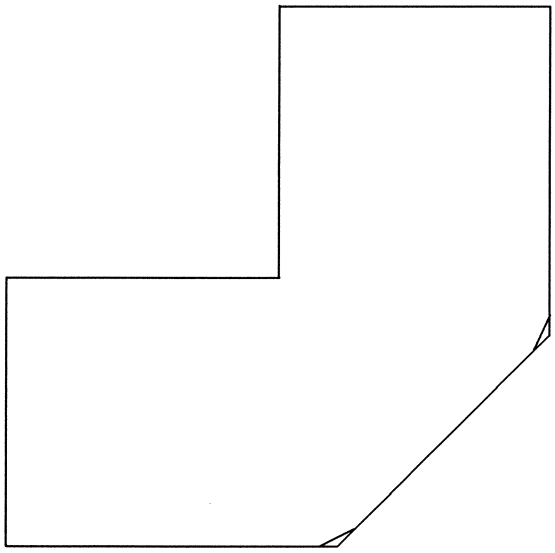
Response of the Optimized Three-Section Mitered Bend



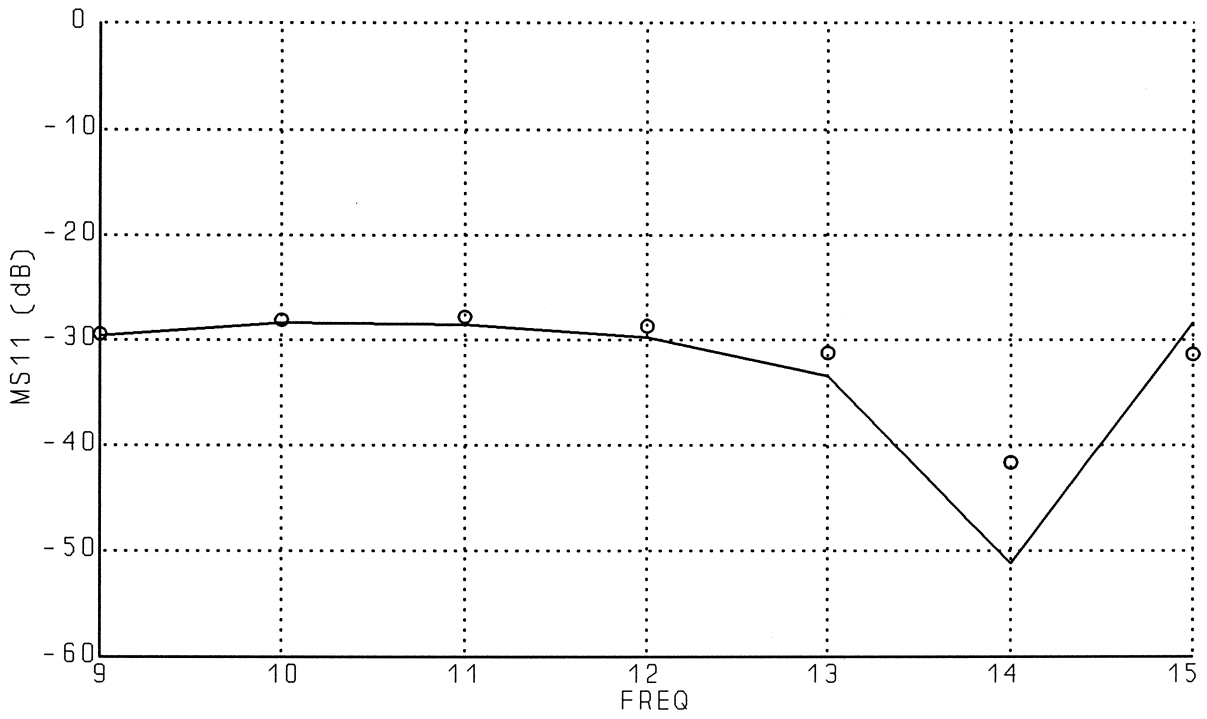
Comparison of the Optimized Geometries







Comparison of the Optimized Responses



the responses of the optimized single-section (lines) and three-section (circles) appear to be very similar