## WAVEGUIDE BEND OPTIMIZATION USING Empipe3D

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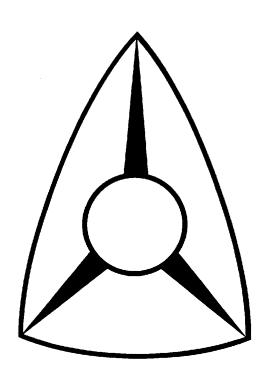
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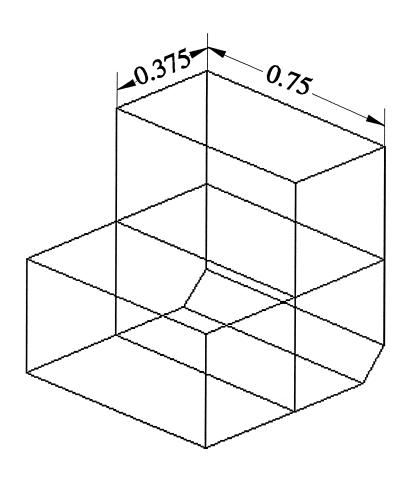
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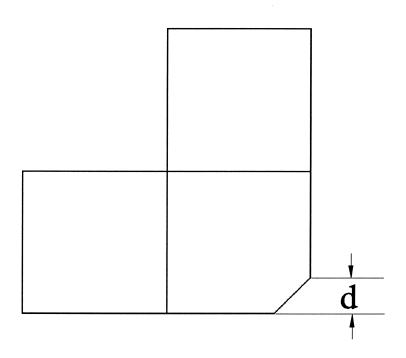




# WR-75 Mitered Waveguide Bend (L.W. Hendrick, Hughes)



#### **Single Section Mitered Bend**



specification in the frequency range from 9.84 to 15 GHz return loss  $\geq$  40 dB

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

$$0 \le d \le 0.375$$
 inch

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



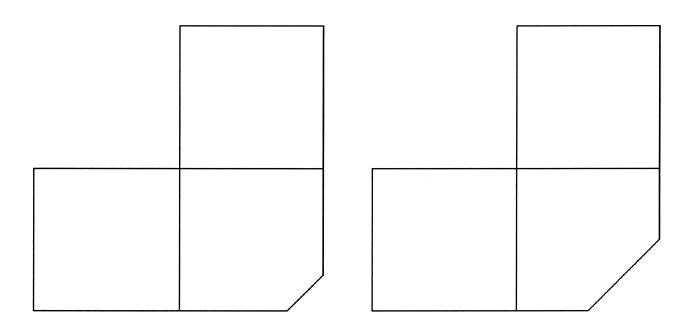
### **Empipe3D Geometry Capture**

	Empipeso vi.o						
	(c) 1996 USA Load Element  Mominal Project: bnd		Save Elenent	Sinulate Optinize	Quit		
	Paraneter Nane	Project Nane	Yalue	Yalue	# of Grids	Unit Nane	
	_ <b>d</b>	bnd03	0.1	0,2	1	in	
: .							

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

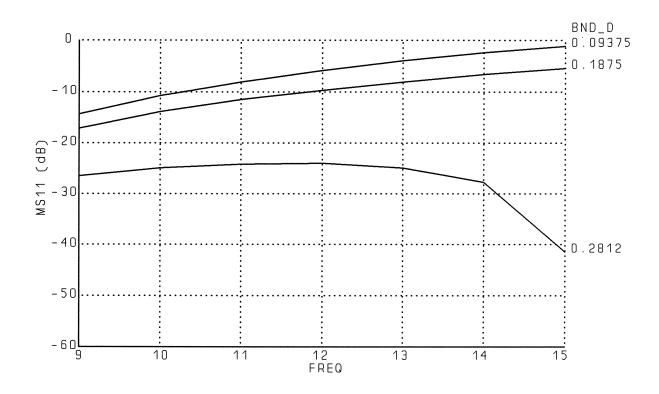
for the mitered waveguide bend, project.sld is the only file dependent on the parameter d

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

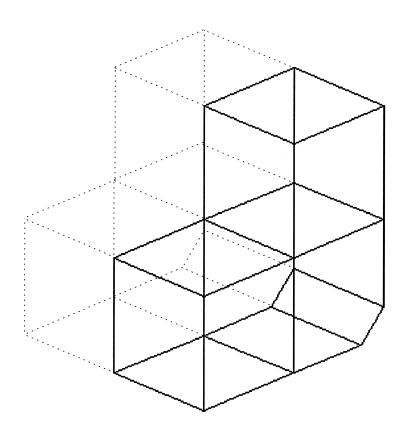
simulation time is approximately 8 CPU hours for each value of d (SPARCstation 10, 9 adaptive meshing iterations)



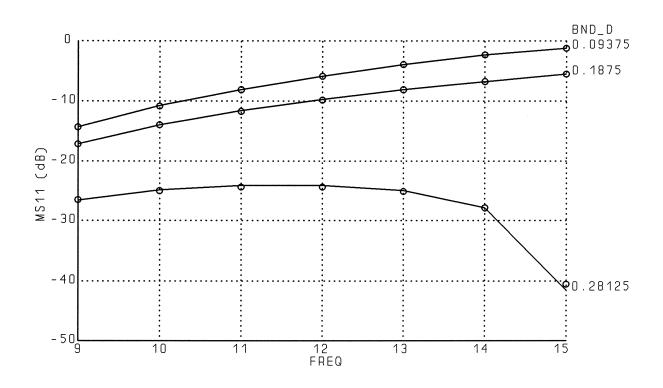
#### Geometric Symmetry of the Waveguide Bend

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



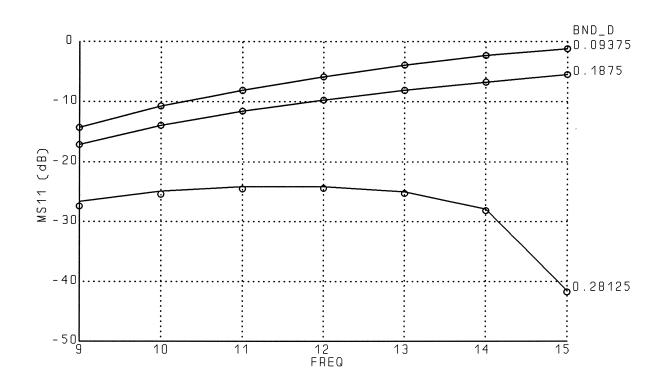
#### Simulation Results with and without Using Symmetry



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

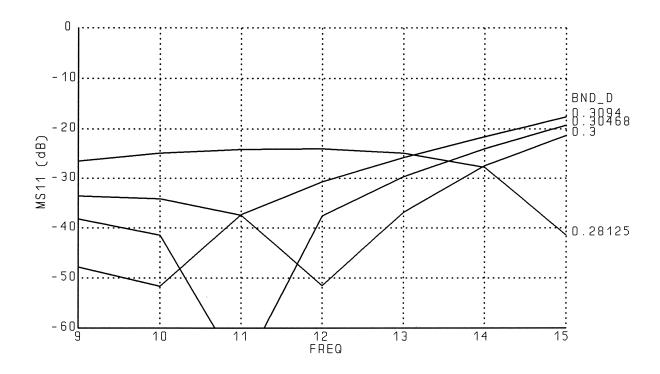
the ratio of CPU simulation times is approximately 3:1

#### Comparison of HFSS and Maxwell Eminence



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

#### Fine Sweep of the Parameter "d"

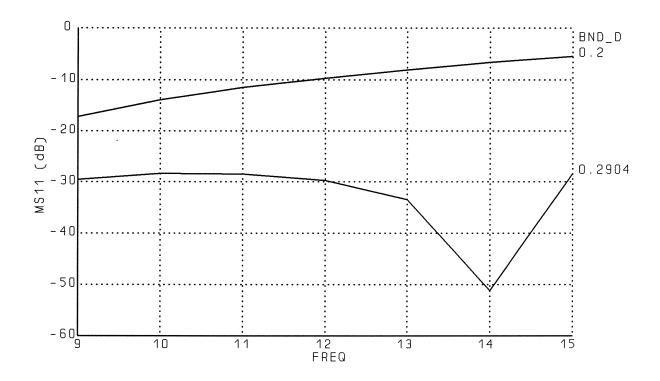


to emulate design by hand, we sweep d with these values: 0.28125, 0.3, 0.304675 and 0.3094 inch

by visual inspection, we can relate the position of the return loss pole to the parameter d as  $1 \, \mathrm{GHz} / 0.005$  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

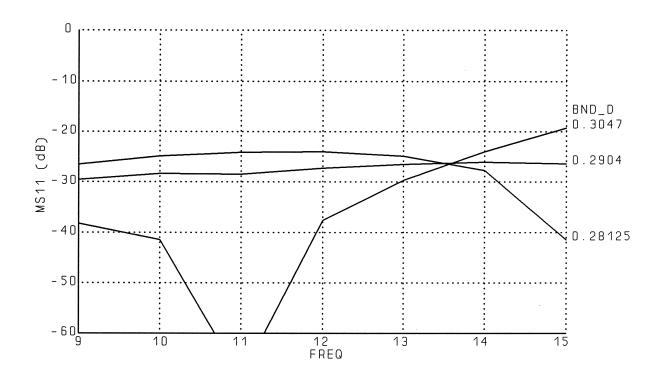
solution:

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**

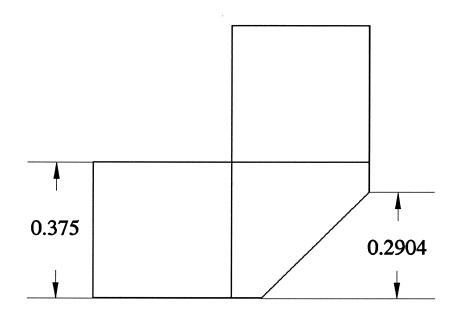


linear interpolation based on the magnitude and phase of the S parameters fails to preserve the notch

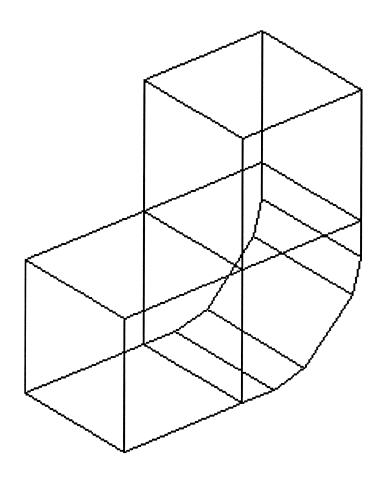
the problem is overcome using linear interpolation on the real and imaginary parts of the S parameters (by setting the Empipe3D parameter MODEL=7)



## The Optimized Mitered Bend



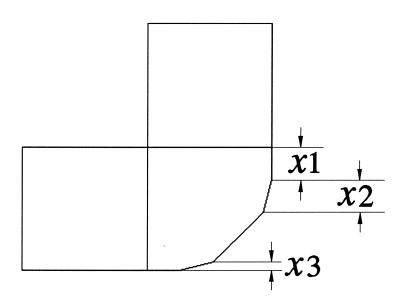
#### **Three-Section Mitered Bend**



"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

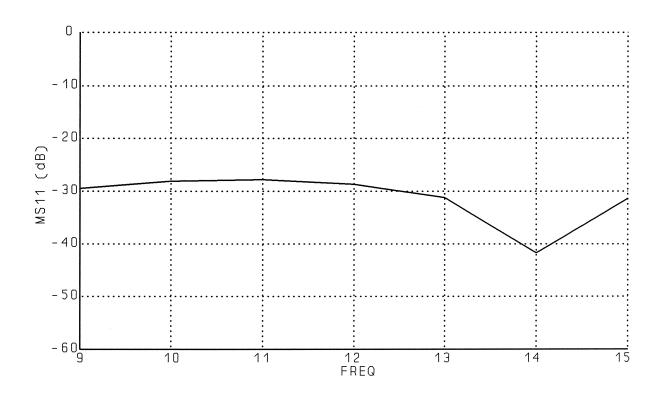
appropriate constraints:

$$x1 > 0$$
,  $x2 > 0$ ,  $x3 > 0$ 

$$x1 + x2 + x3 < 0.375$$
 inch

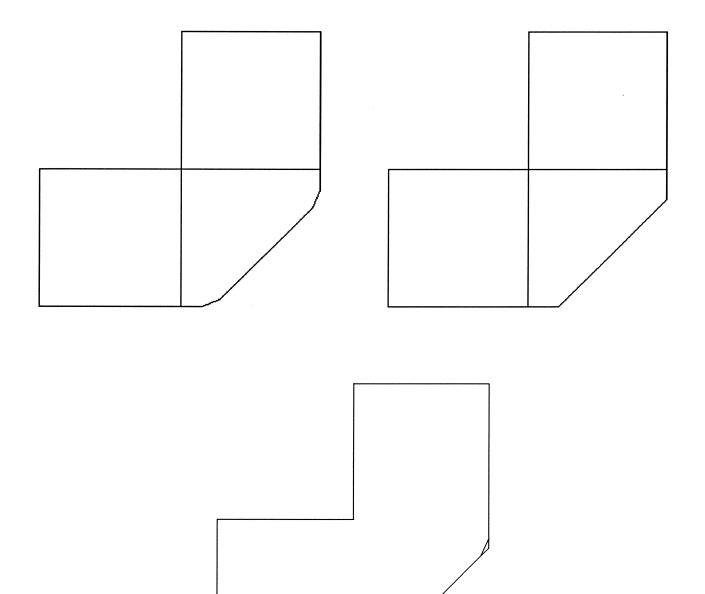


## Response of the Optimized Three-Section Mitered Bend

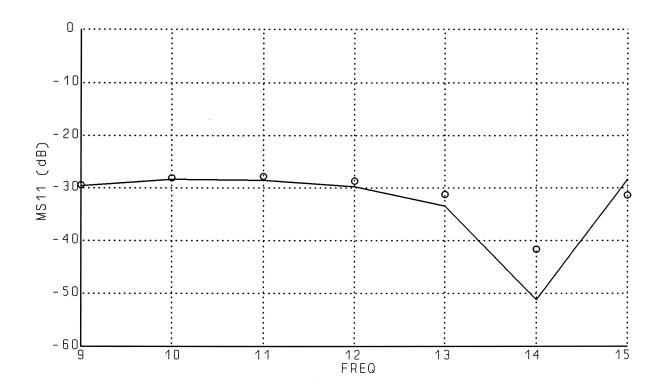




## **Comparison of the Optimized Geometries**



#### **Comparison of the Optimized Responses**



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