Turnstile Junction Orthomode Transducer

An option for EVLA X-Band Receiver

X-Band OMT Design Review Meeting; AOC, Socorro; October 1, 2009

Sivasankaran Srikanth, Scientist/Research Engineer

Miles Solatka & Designer

Michael Meek Machinist

NTC-CDL

Atacama Large Millimeter/submillimeter Array
Expanded Very Large Array
Robert C. Byrd Green Bank Telescope
Very Long Baseline Array

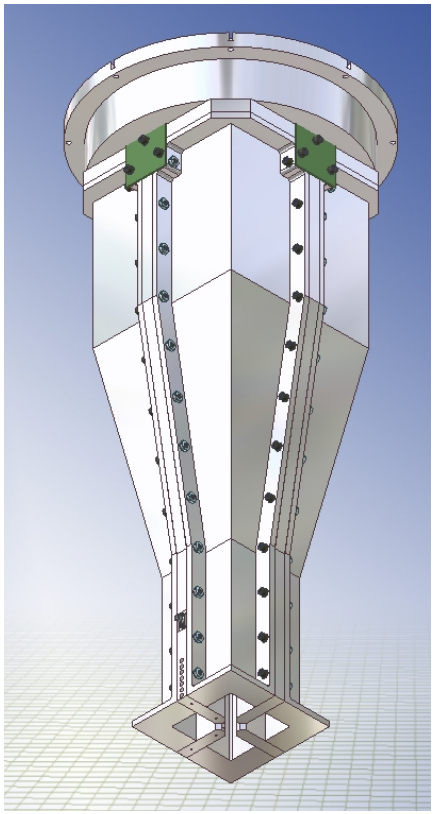
NRAO

Contents

Specifications of X-band OMT

Bandwidth 8 to 12 GHz (1.5:1 BW ratio)
Return loss > 25 dB
Insertion loss ≤ 0.2 dB
Crosspolarization ≤ -40 dB
Isolation ≤ -40 dB
Size ??????
Weight ?????

Septum Polarizer, Quadridged OMT



Septum Polarizer Length ~ 3.75" (2.7λ); BW ratio 1.28:1

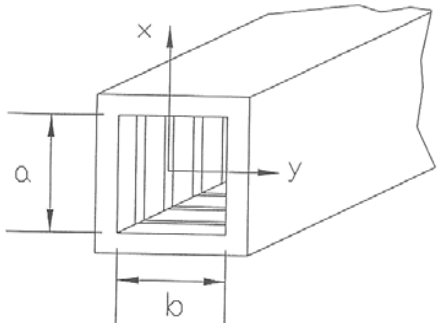
L-band Quadridged OMT scaled to 8 to 12 GHz; Length = 3.975" (3.4λ)

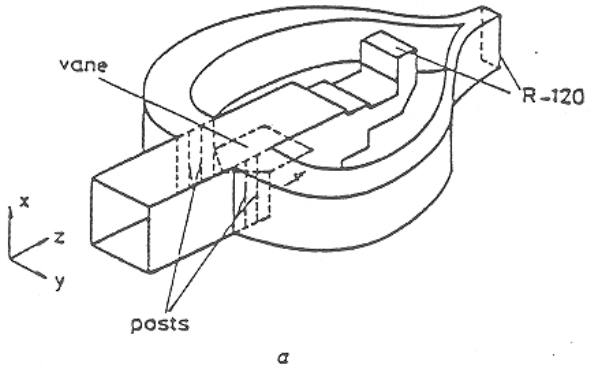
BW ratio 2:1

Boifot Junction OMT

Lengths:
Circular-square transition = 2.318”
Phase shifter = 7.875" (6.67λ)
45 twist = 3.454"
Boifot OMJ = 6.400" (5.4λ)
Total = 20.047”

(OMJ scaled from Ka-band)





BW ratio ~1.5:1

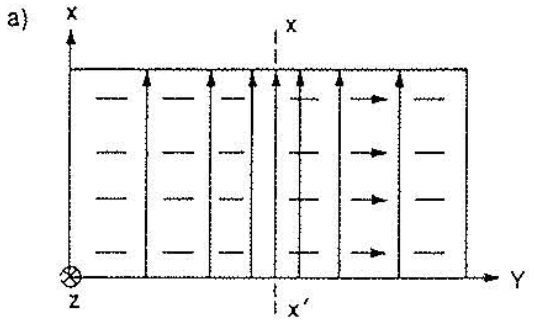
Symmetrical and Odd-symmetrical modes

$$\lambda_c = \frac{2}{\sqrt{\left(m/x_1\right)^2 + \left(n/y_1\right)^2}}$$

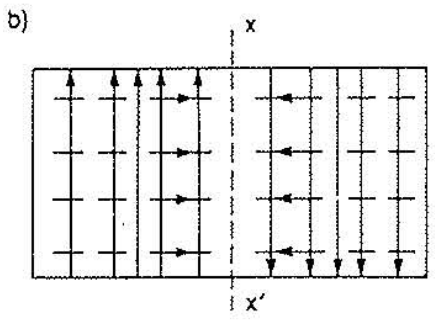
Anton M. Beifot — Classification of Ortho-Mode Transducers

$\lambda_c = 2a$

f_c= 6.557 GHz



TE_{01}



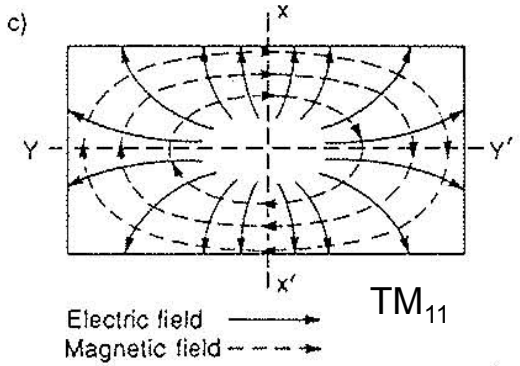
TE_{02}

$\lambda_c = a$

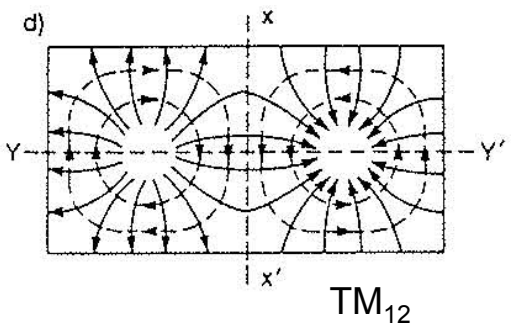
f_c= 13.114 GHz

$$\lambda_c = \frac{2a}{\sqrt{1 + \left(a/b\right)^2}}$$

f_c= 16.145 GHz (rect.)
f_c= 9.272 GHz (sqre.)



TM_{11}



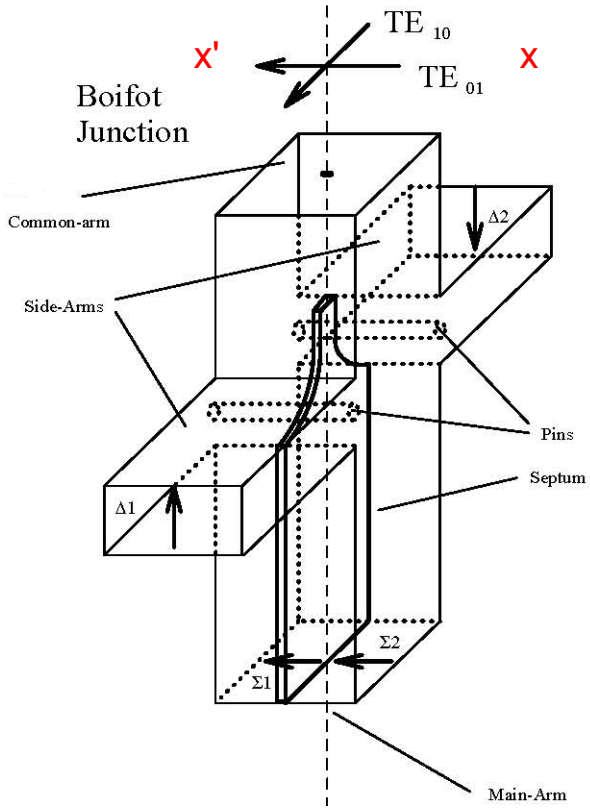
TM_{12}

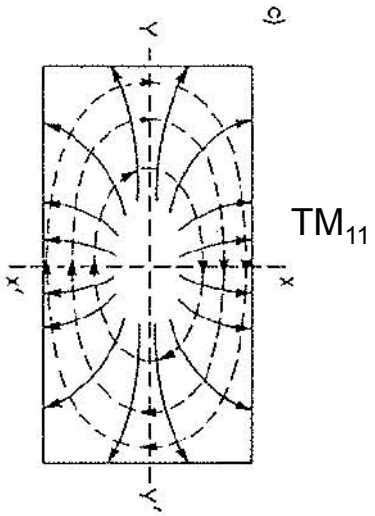
$$\lambda_c = \frac{a}{\sqrt{1 + \left(a/2b\right)^2}}$$

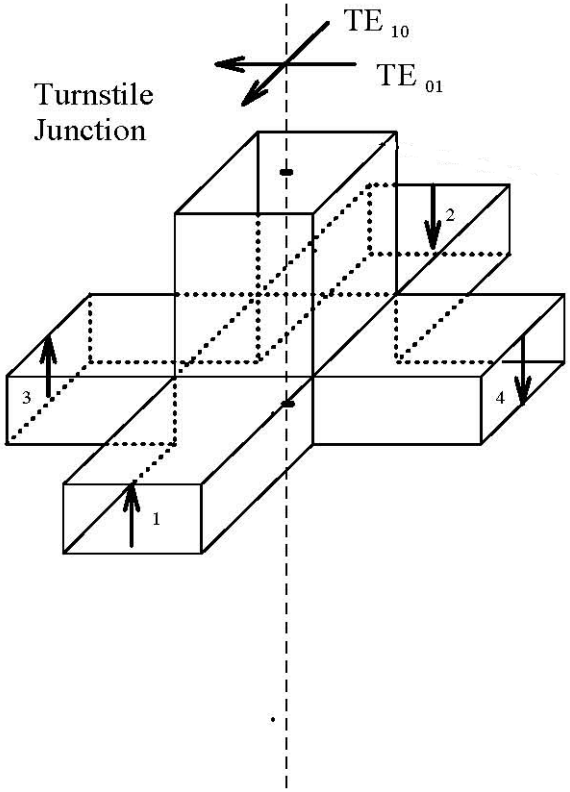
f_c= 19.739 GHz (rect.)
f_c= 14.662 GHz (sqre.)

Fig. 1 - Definition of symmetry. The TE_{01} mode in a) is symmetrical about XX′, the TE_{02} mode in b) has odd symmetry about XX′, the TM_{11} mode in c) is symmetrical both about XX′ and YY′, while the TM_{12} mode in d) has odd symmetry about XX′ and symmetry about YY′.

Turnstile Junctions







E-plane, H-plane bends

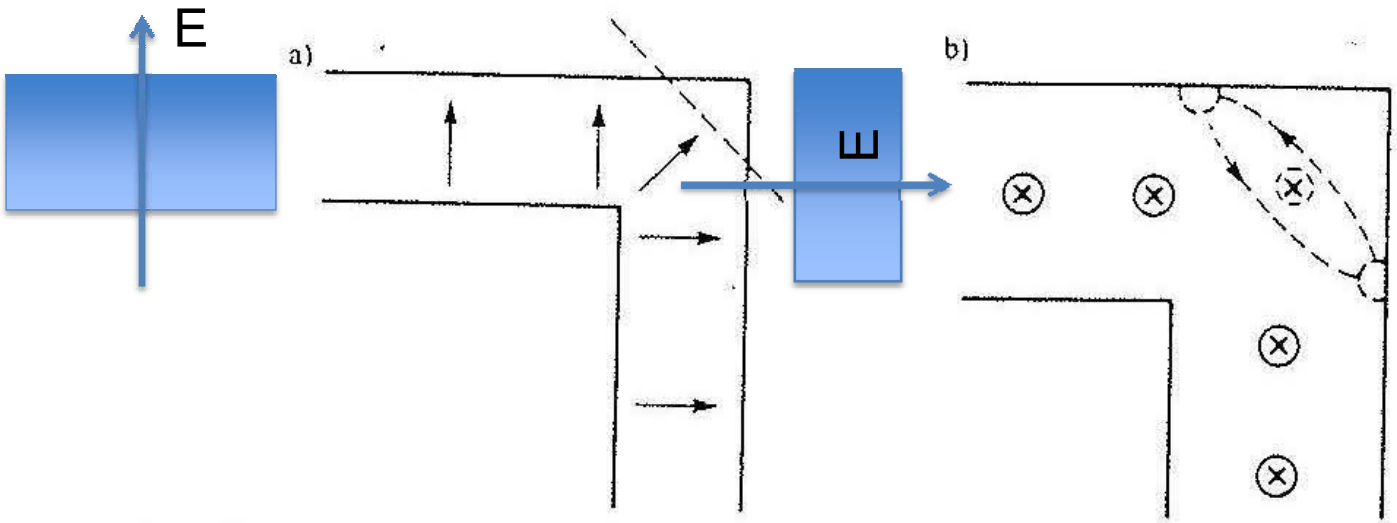
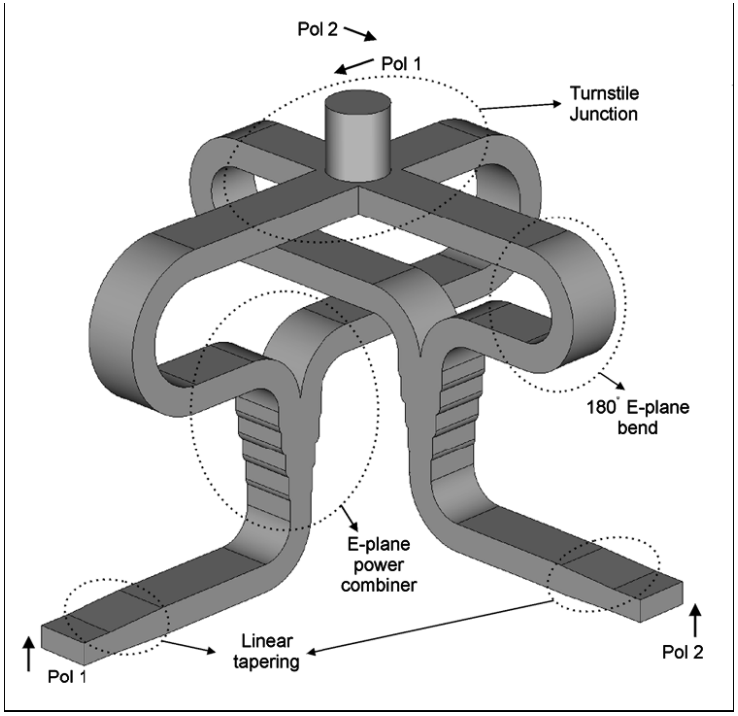
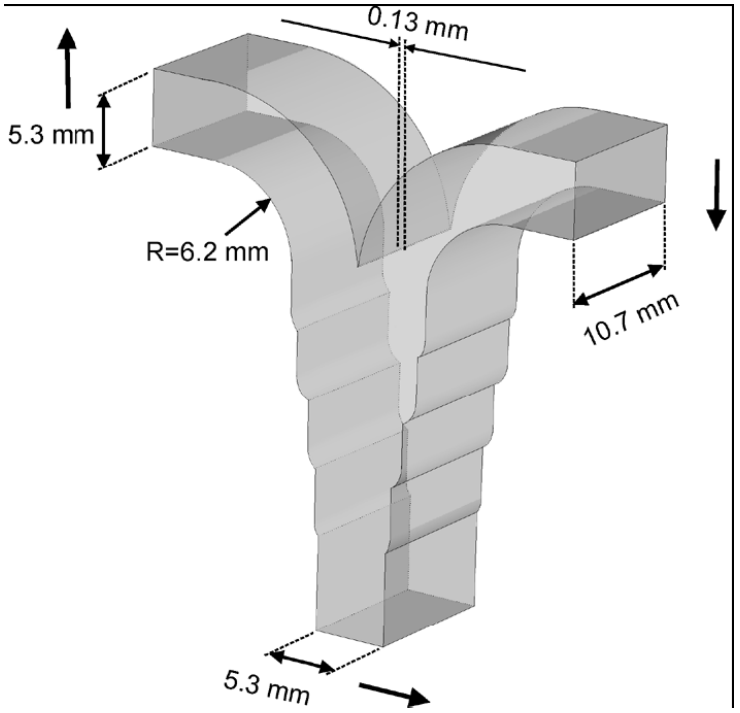


Fig. 4 - Corners with different matching properties. The *E*-plane bend in a) generates only symmetrical modes, while the *H*-plane bend in b) generates both symmetrical and odd symmetrical modes.

A Turnstile Junction Waveguide Orthomode Transducer

A. Navarrini and R. L. Plambeck





18-26 GHz; Circ. Dia=0.457 "; Waveguide=0.420"x0.208"; Stub: 0.173"x0.173"x0.087";Prototype for 210 to 270 GHz

S_{11}< -23 dB (Turnstile jn.) ; S_{11}<-32 dB (combiner) ; Linear taper to 0.420"x0.170" – S_{11}<-33 dB

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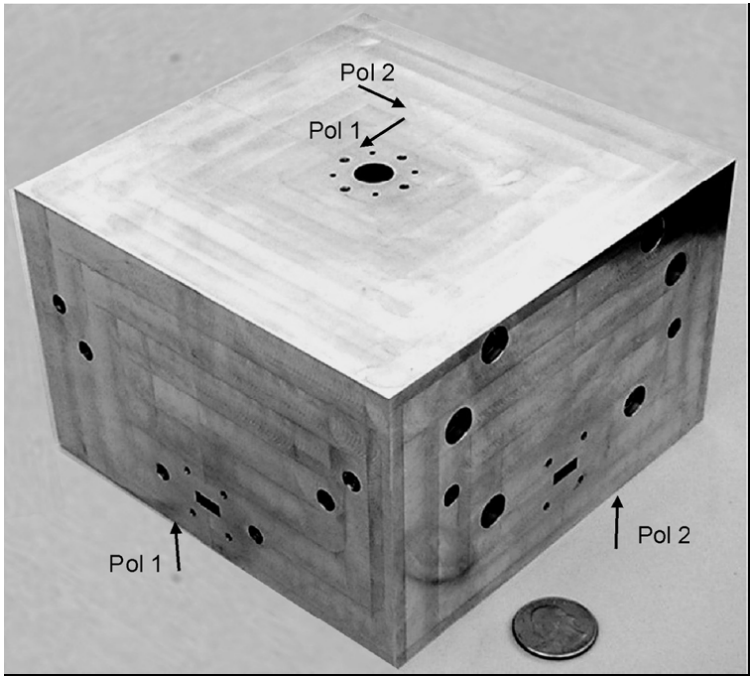
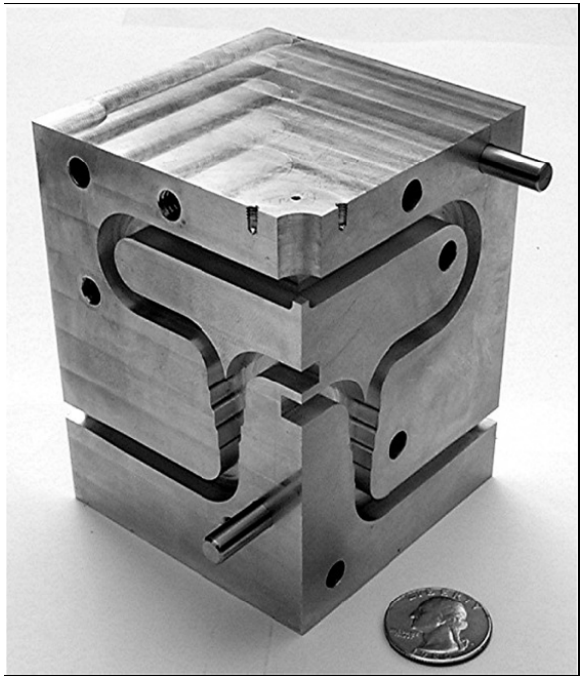
A. Navarrini and R. L. Plambeck

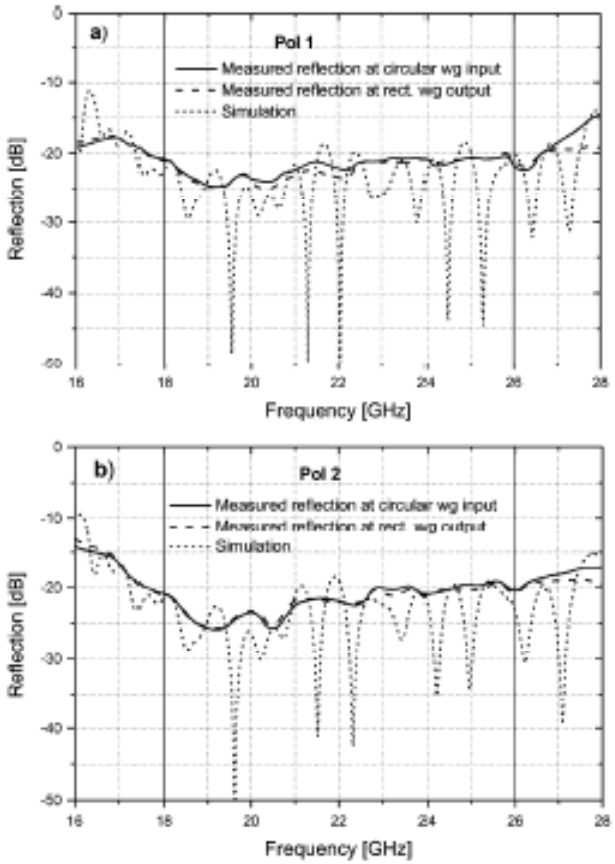


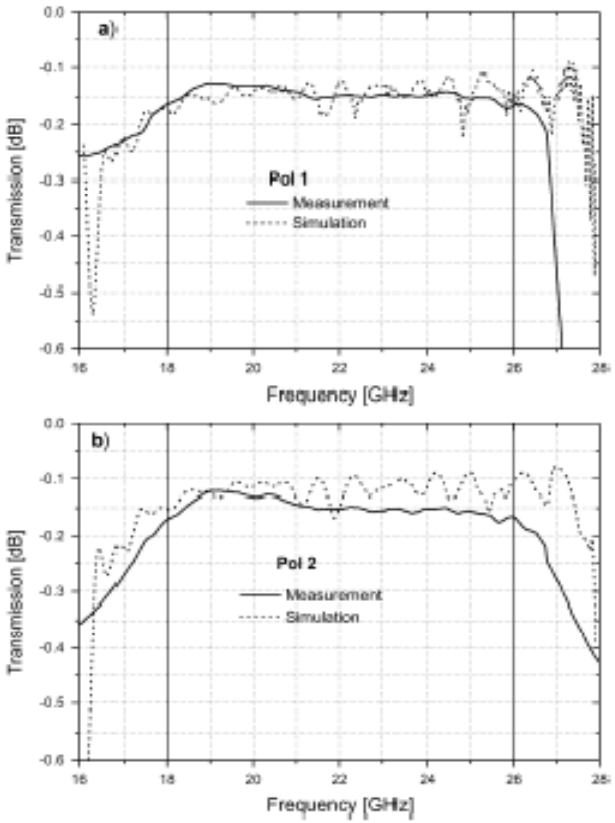


Split in E-planes; Path length = 9.84" (25 cms); External dim: 5.8"x5.8"x3.8"

A Turnstile Junction Waveguide Orthomode Transducer

A. Navarrini and R. L. Plambeck



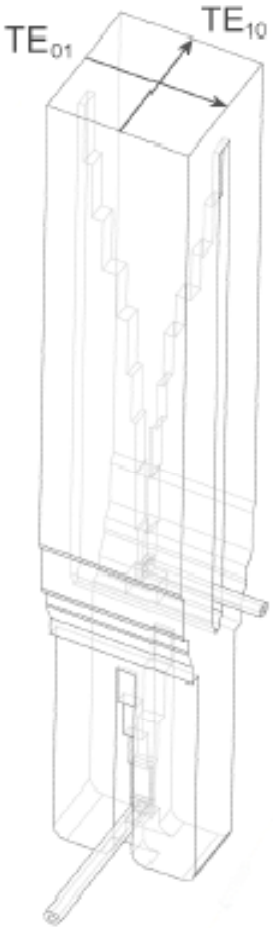


S11< -19 dB; S21 ~ -0.15 dB; Isolation <-48 dB; (over 1.44:1 BW)

Scaling to X-band 13"x13"x8.5"

Double Ridged Orthogonal Mode Transducer for the 16-26 GHZ Microwave Band

Alex Dunning



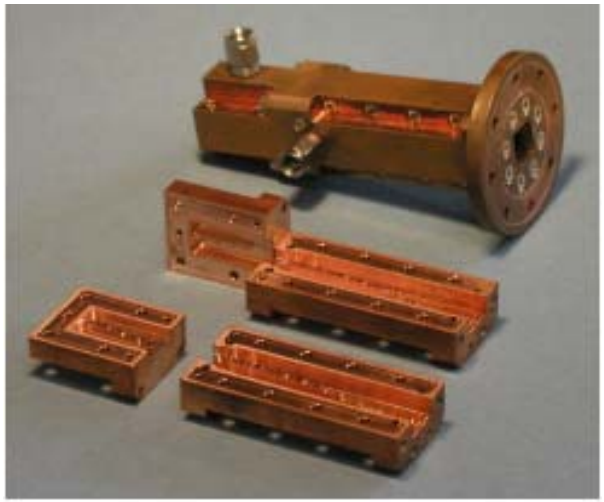


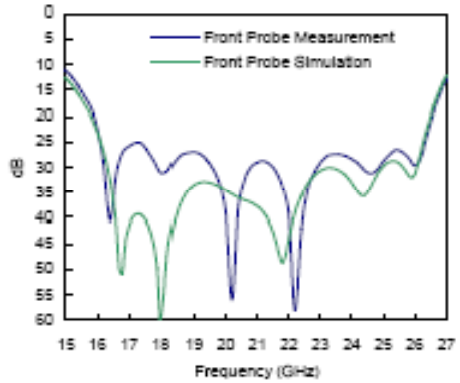
Figure 1a. Complete copper OMT and split sections

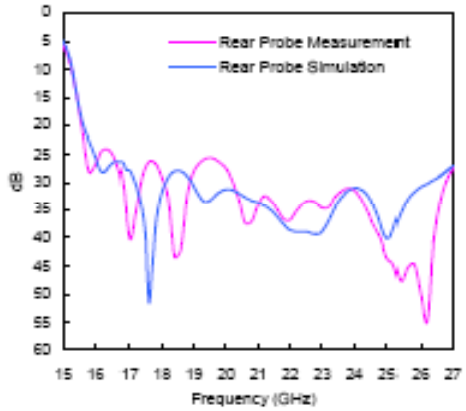
Split planes perpendicular to ridges

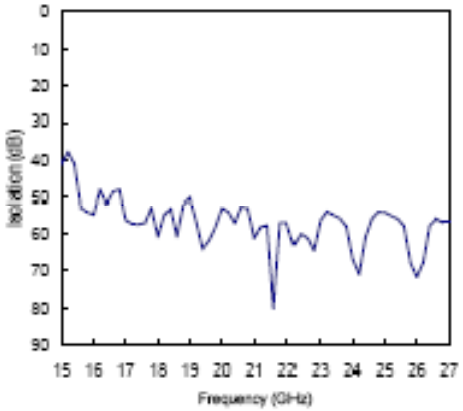
9 steps for TE01; Ridge t=0.055”
NOT SYMMETRICAL; All modes except TE10 cut off in Rect. Wg.

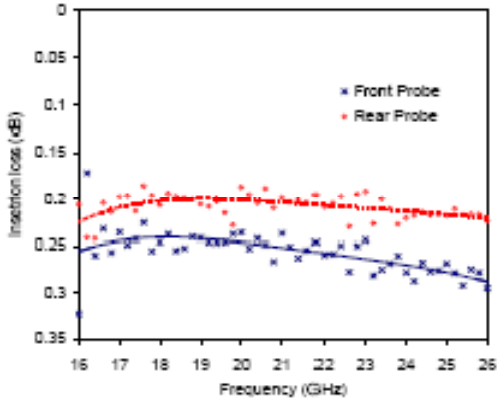
Double Ridged Orthogonal Mode Transducer for the 16-26 GHZ Microwave Band

Alex Dunning









S_{11} <-25 dB; Isolation <-40 dB; Insertion loss < -0.25 dB (frnt); <-0.20 dB (rear) over 1.6:1 BW

Length = 3.4" (16 – 26 GHz)
Scaling to X-band L=7.3"

Ultra-Thin Broadband OMT with Turnstile Junction

Y. Aramaki, N. Yoneda, M. Miyazaki and T. Horie
Mitsubishi Electric Corporation

Ku-band (10-15 GHz)

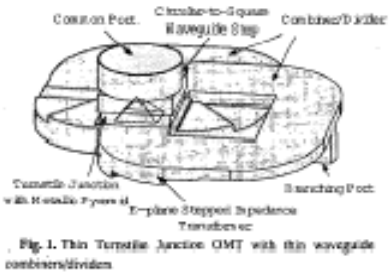
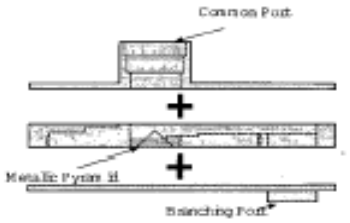


Fig. 1. Thin Turnstile Junction OMT with thin waveguide combiners/dividers



Circ. To Sq. transition – dia : 0.945", I step: 0.748"x0.748", II step: 0.630"x0.630 "

Turnstile Jnc.- Rect. Waveguide 0.630"x0.315", Pyrmd. Stub 0.394"x0.394"x0.275"

Combiner – E-pln stepped imp. Transformer, H-pln bend, E-pln T-junction 0.630"x0.236“
(h=0.315 t0 0.118)

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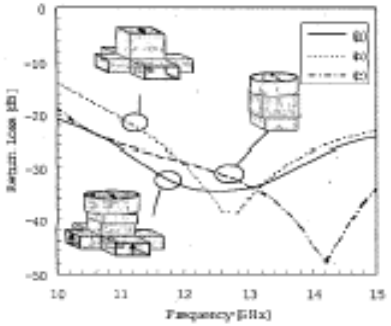
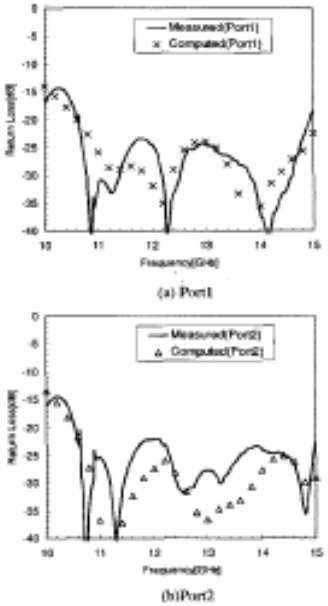


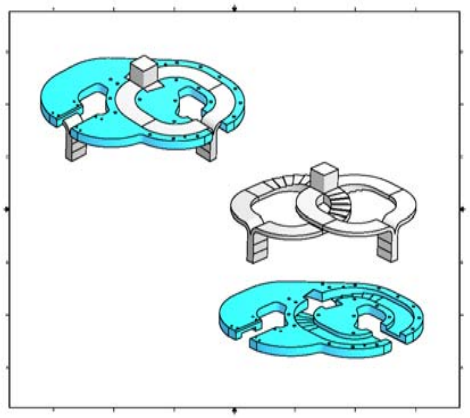


S_{11} : Turnstile jnc. with stub <-14 dB (10-15); <-20 dB (11.5-15)
Turnstile jnc. with stub + Cir. To sq. step <-20 dB (10-15)

OMT S_{11} <-22 dB (11-15); <-15 dB (10-15)
Insertion loss <0.1 dB
Isolation better than -40 dB

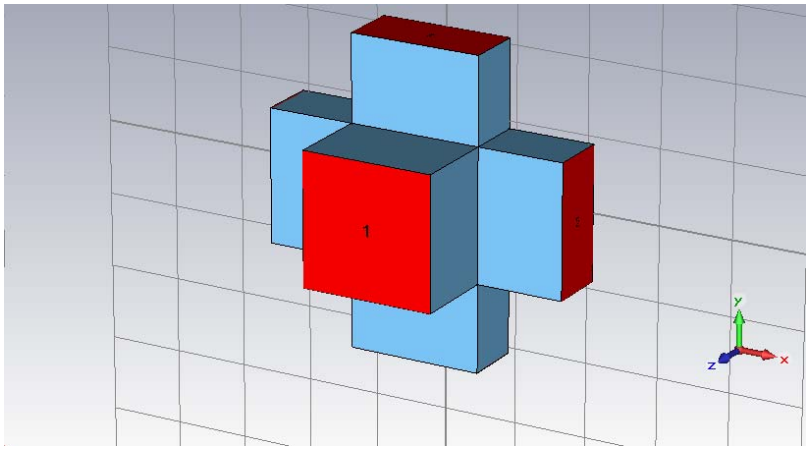
Height from bottom of II step to bottom of combiner = 0.800";
Cross-section dia ~ 5.5"
Scaling to X-band : Ht = 1.000"; Dia = 7.0"

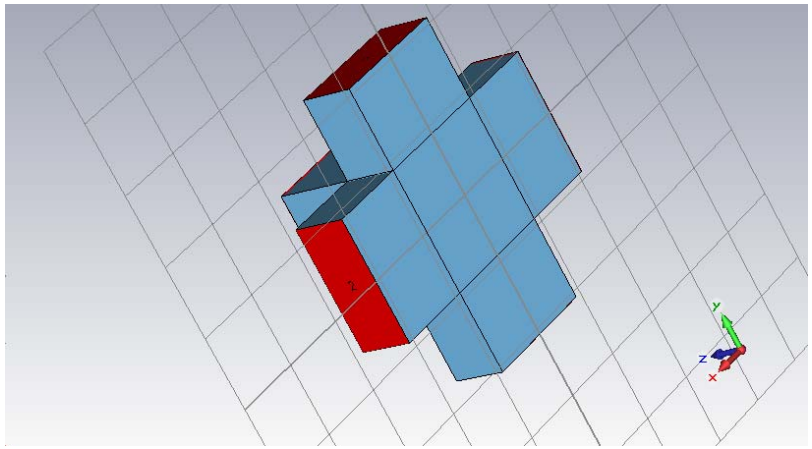
Optimization Of Components Of The OMT

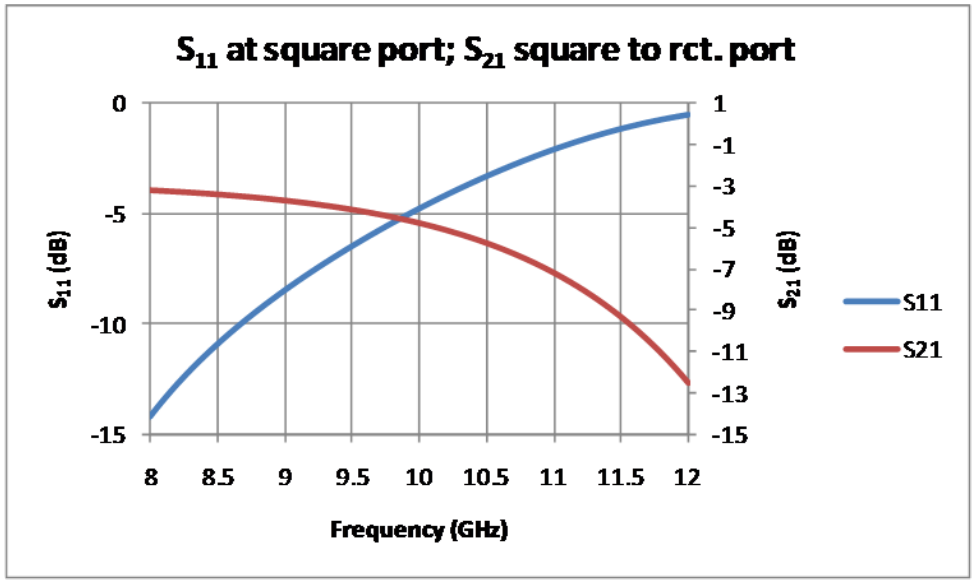


- 1. Turnstile Junction
- 2. Side arms with waveguide bends
- 3. 0.900x0.400 to 0.900x0.180 stepped transformer
- 4. Y-Junction
- 5. 0.900x0.380 to 0.900x0.400 stepped transformer
- Used CST Microwave Studio in all the optimization and analysis

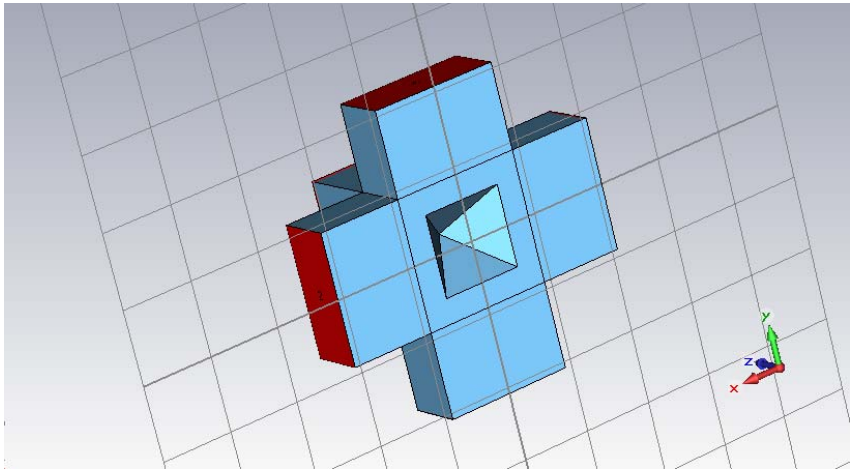
Turnstile Junction

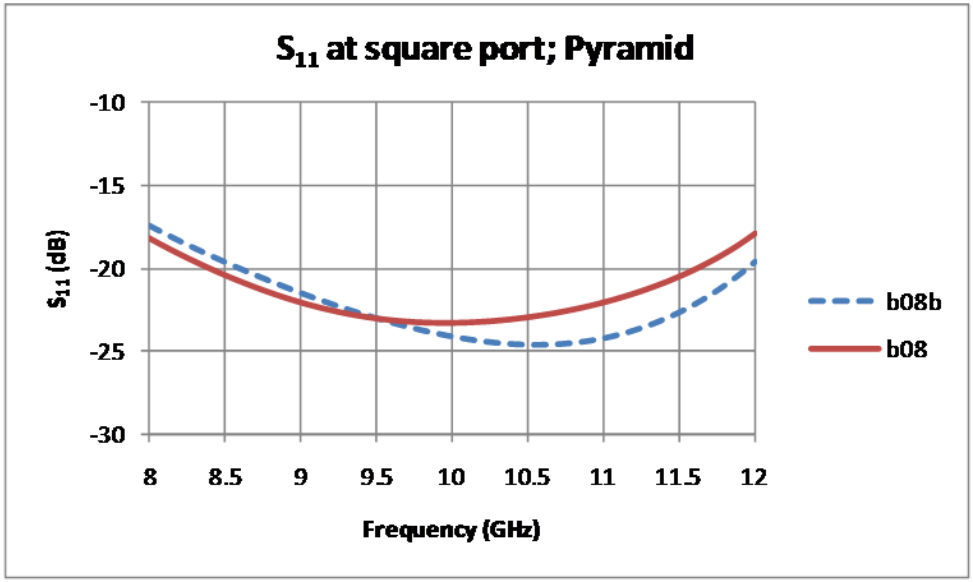






Turnstile Junction with pyramidal stub



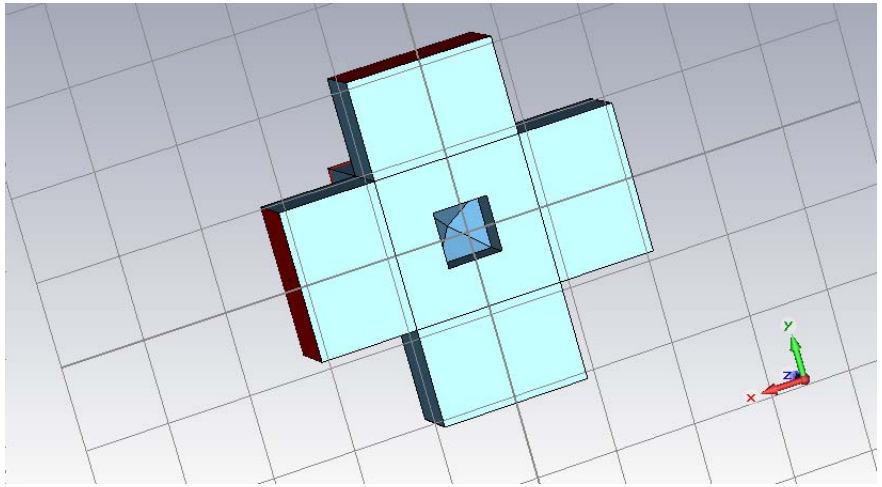


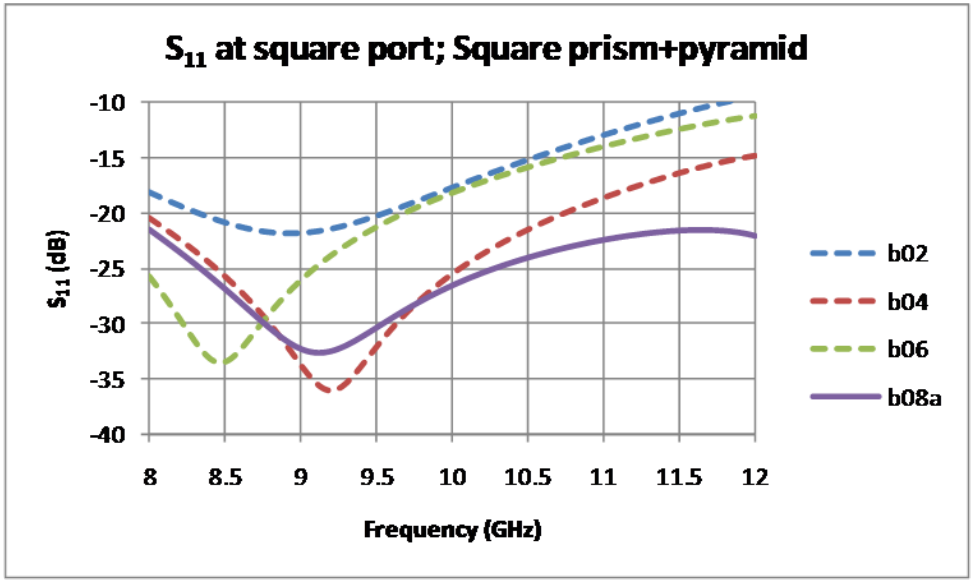
	side	pyh
b08b	0.562	0.394*
b08	0.562	0.373

$S_{11} \leq -17.9$

*Aramaki et.al.,"Ultra-Thin Broadband OMT with Turnstile Junction," 2003 IEEE MTT-S Digest

Turnstile Junction with square prism + pyramid stub

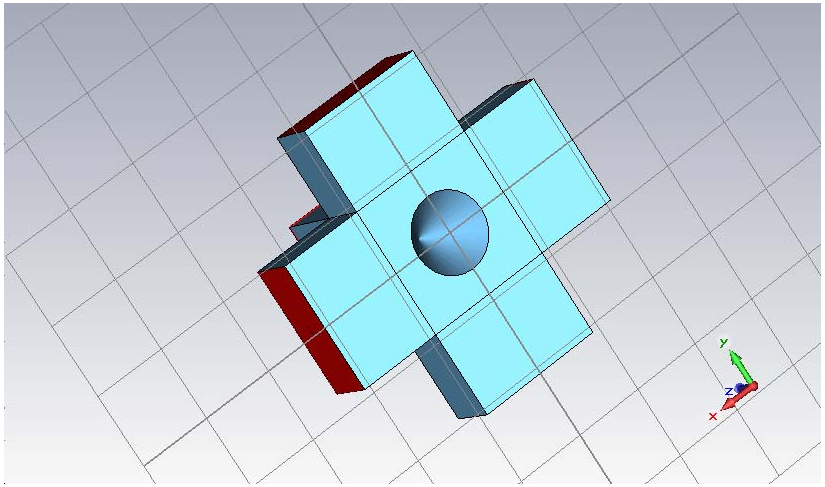


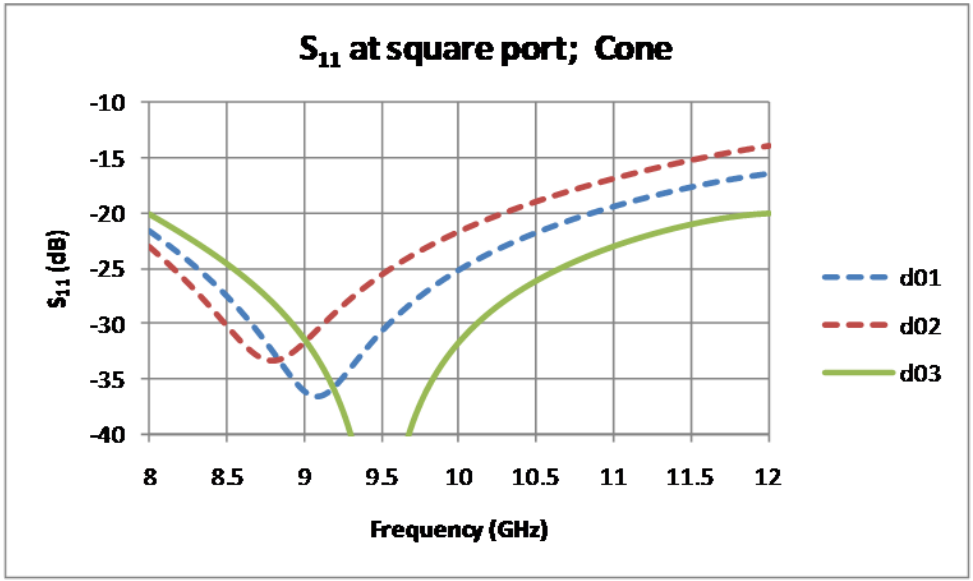


	side	h	pyh
b02	0.335	0.210	0.200
b04	0.335	0.210	0.100
b06	0.300	0.210	0.090
b08a	0.335	0.210	0.030

$S_{11} \leq -21.4$

Turnstile Junction with conical stub

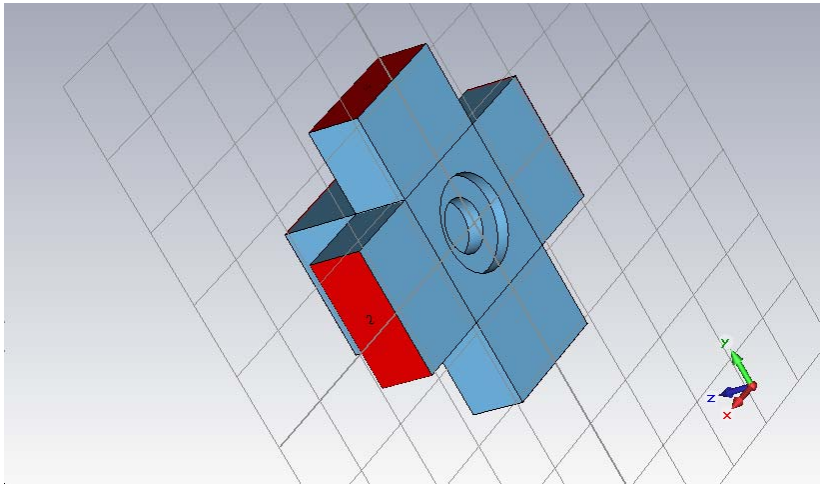


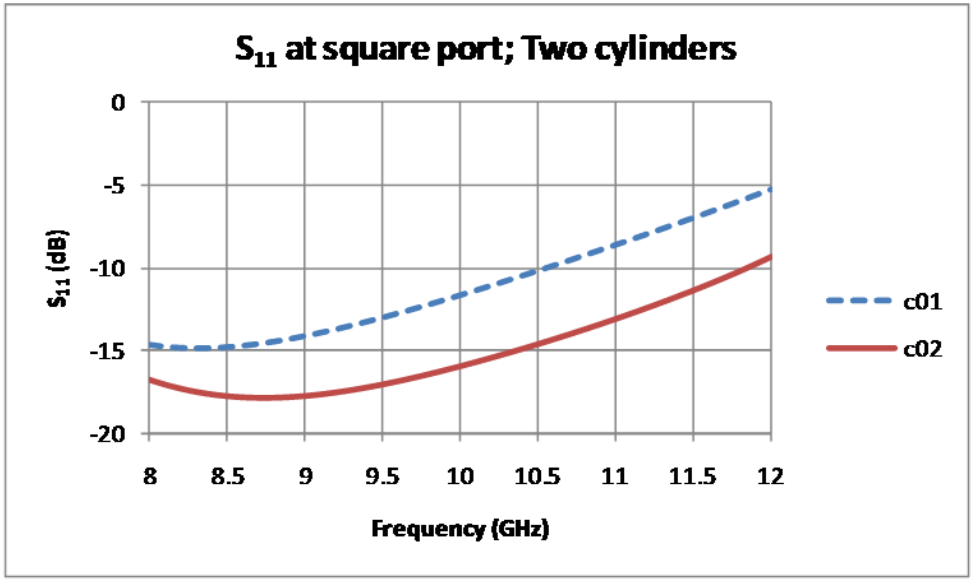


	dia	ht
d01	0.530	0.445
d02	0.510	0.445
d03	0.550	0.450

$S_{11} \leq -20.0$

Turnstile Junction with 2 cylinders



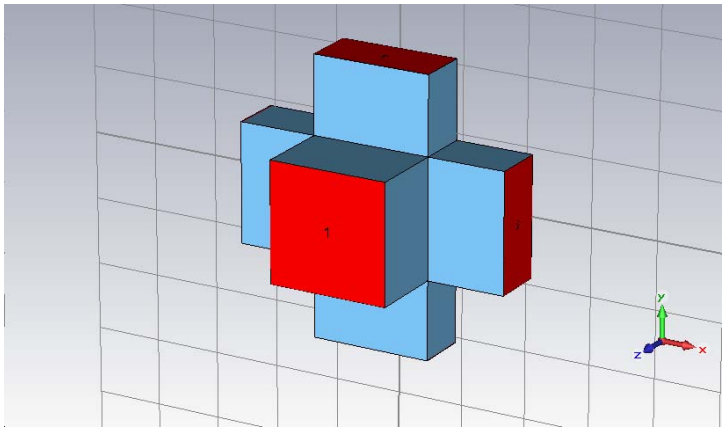


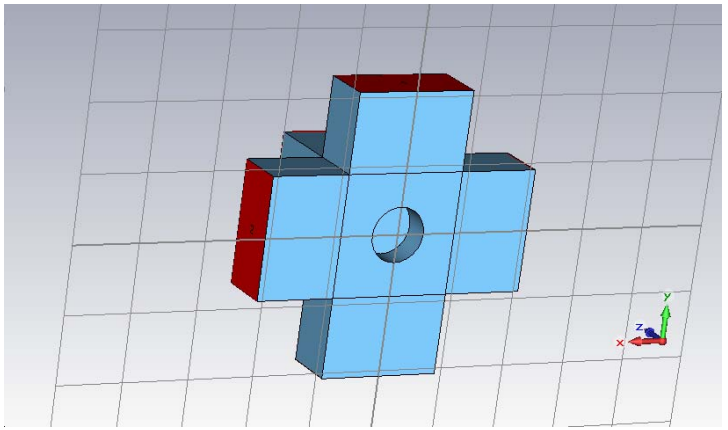
	D	H	d	h
c01	0.705	0.096	0.325	0.184*
c02	0.635	0.086	0.358	0.202

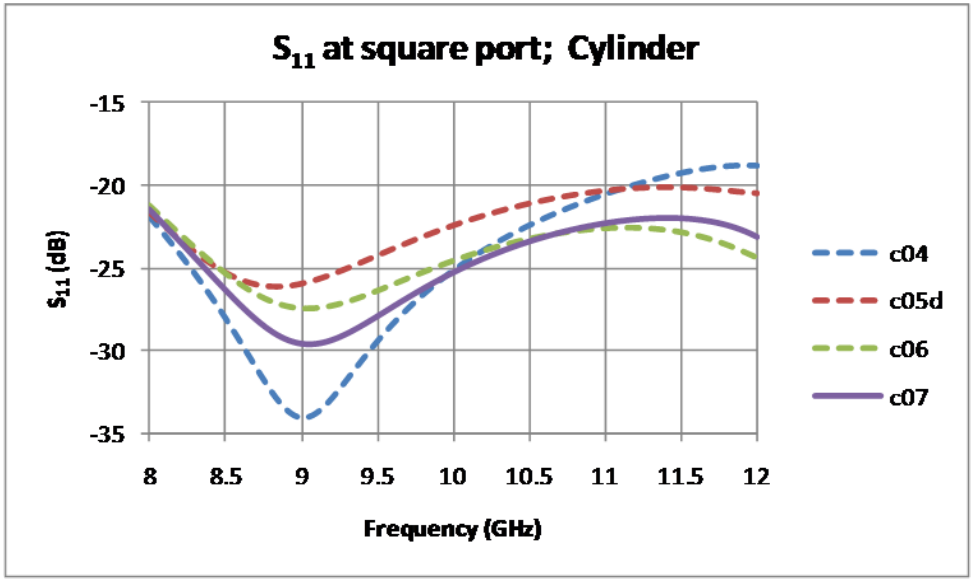
$S_{11} \leq -9.4$

* G. Pisano et. al, "A Broadband WR10 Turnstile Junction Orthomode Transducer," IEEE Microwave and Wireless Comp. Letters, Vol. 17, April 2007

Turnstile Junction with cylindrical stub



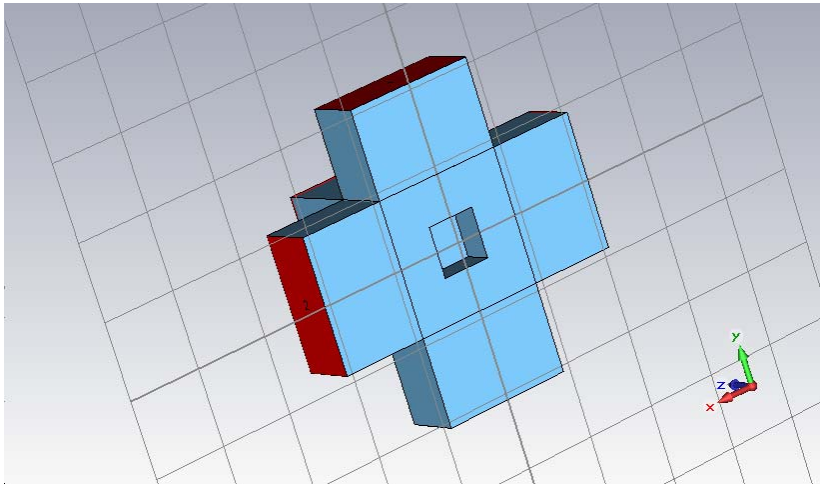


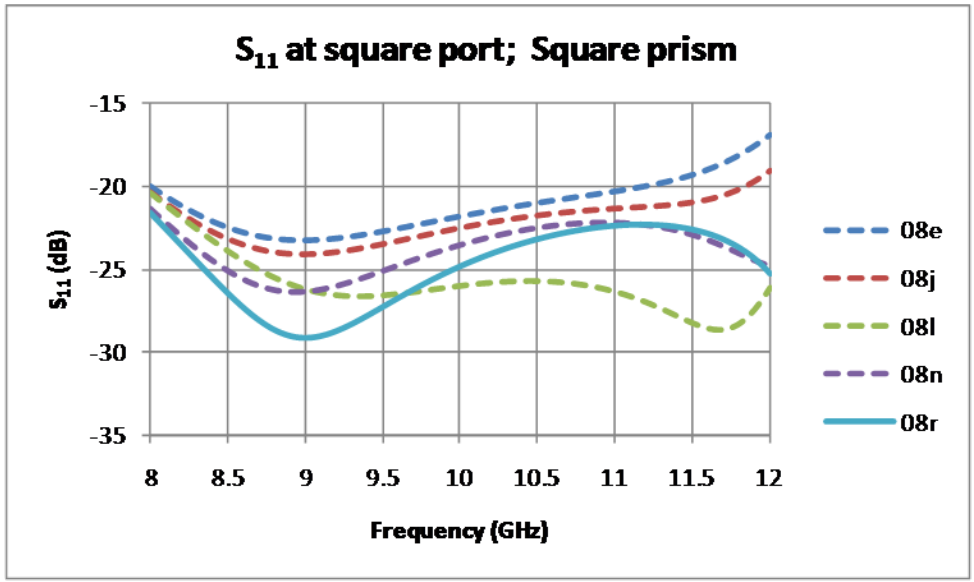


	Dia.	Ht.
co4	0.385	0.217
c05d	0.405	0.195
c06	0.405	0.200
c07	0.396	0.207

$S_{11} \leq -21.5$

Turnstile Junction with square prism



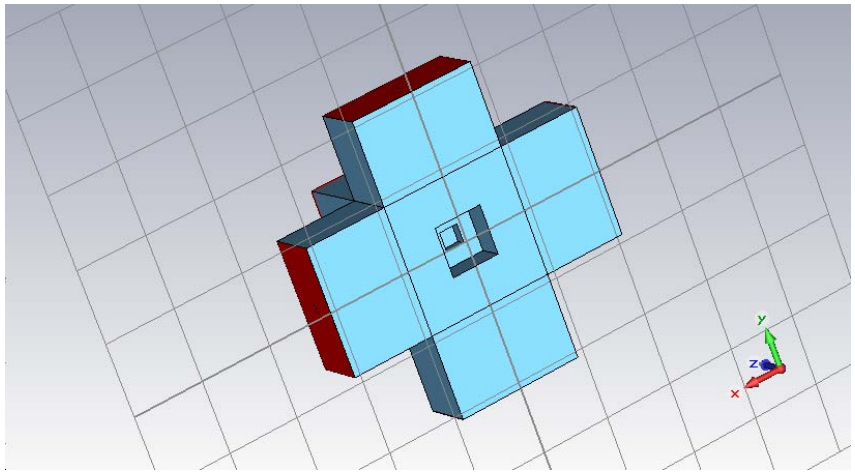


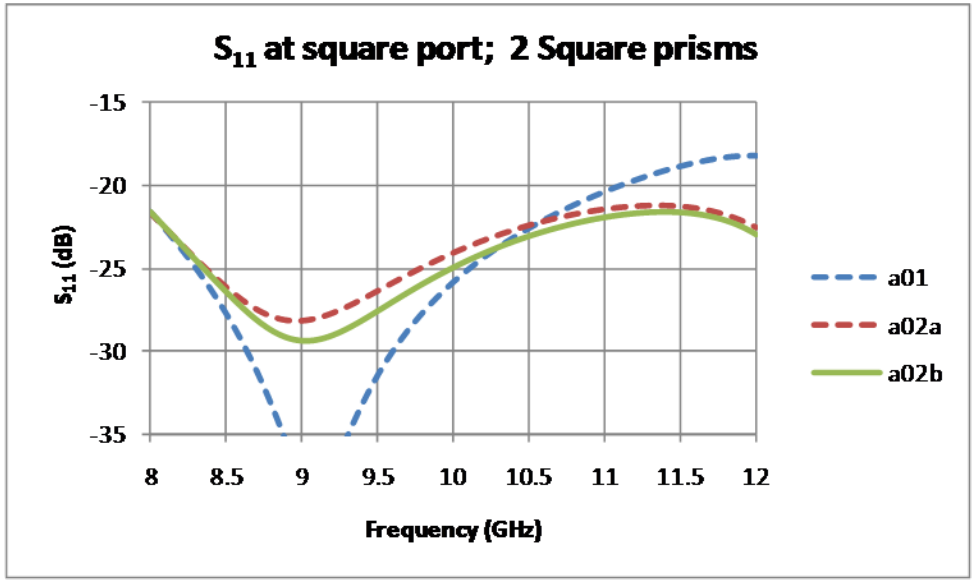
	side	ht	
08e	0.371	0.186	*
08j	0.363	0.190	
08l	0.355	0.200	
08n	0.345	0.200	
08r	0.335	**0.210**	****used this design**

$S_{11} \leq -21.6$

* A. Navarrini and R.L. Plambeck, "A Turnstile Junction Waveguide Orthomode Transducer," IEEE Trans. on Microwave Theory and Techniques, Vol. 54, Jan. 2006.

Turnstile Junctions with 2 square prisms

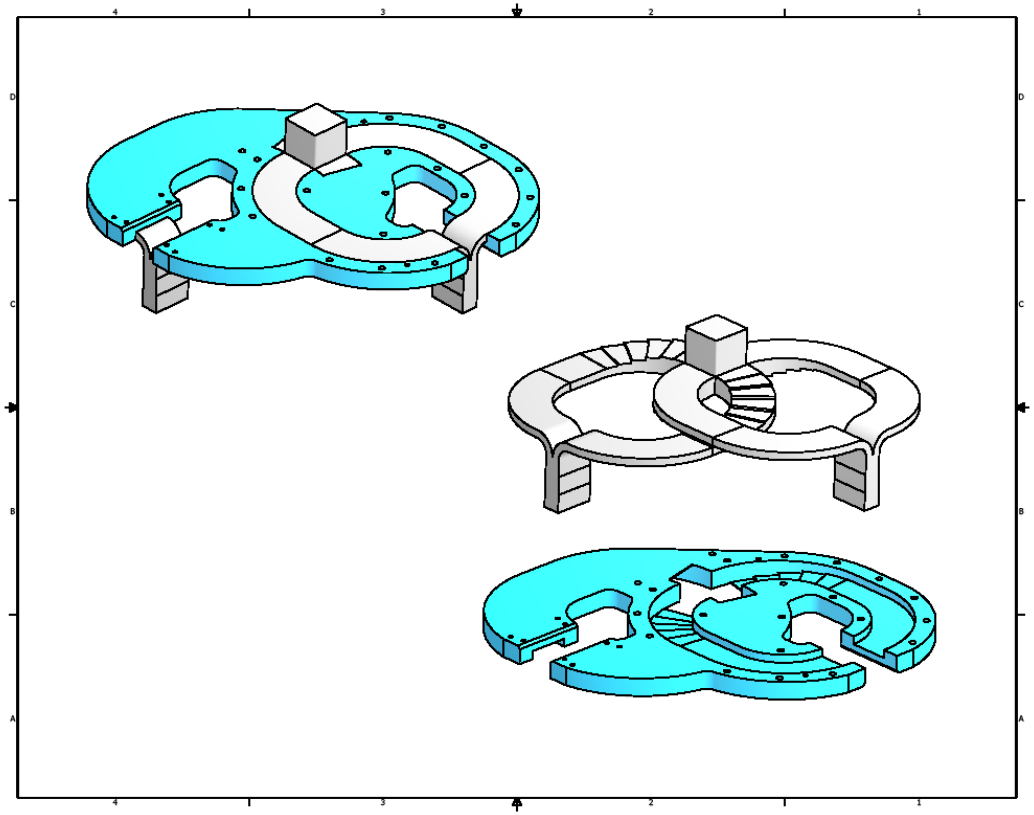




	s1	h1	s2	h2
a01	0.335	0.210	0.128	0.080
a02a	0.348	0.192	0.128	0.080
a02b	0.346	0.195	0.134	0.076

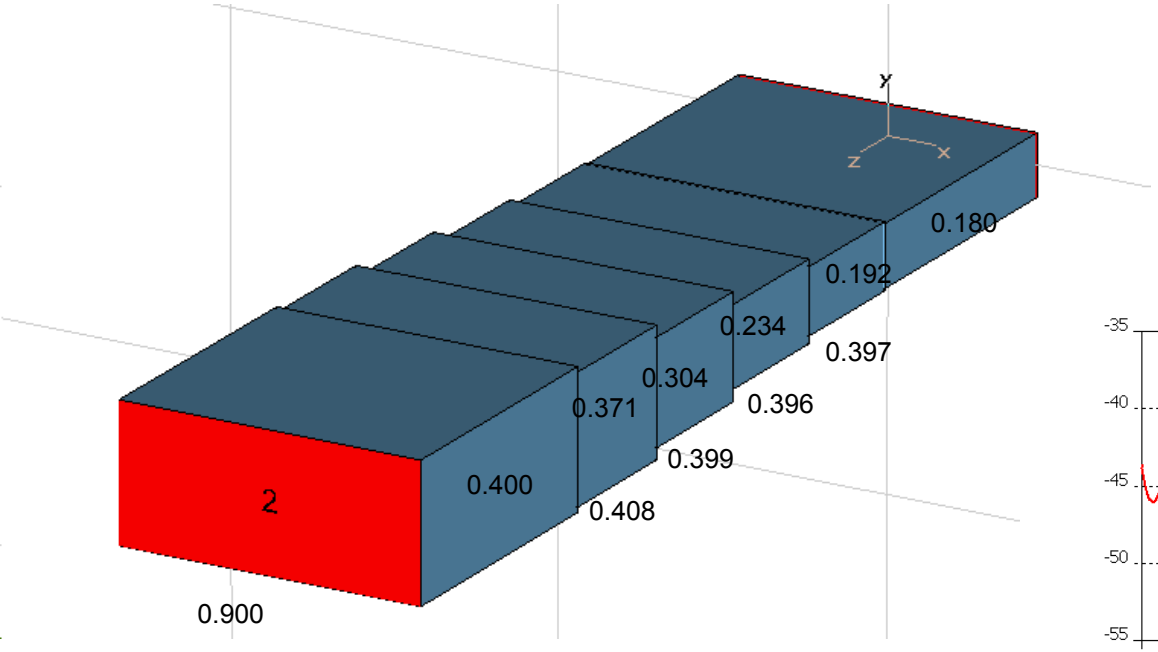
$S_{11} \leq -21.55$

Waveguide Transformer & H-plane Bends in the side arm

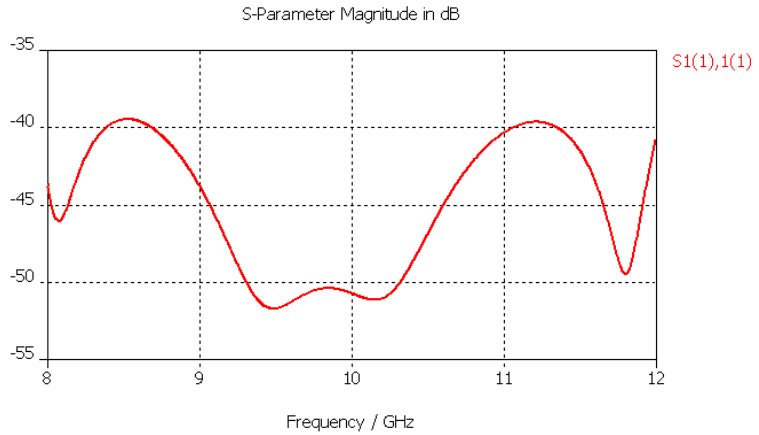


Waveguide Transformer
0.900 x 0.400
to
0.900 x 0.180

4-step Tchebyschev Transformer

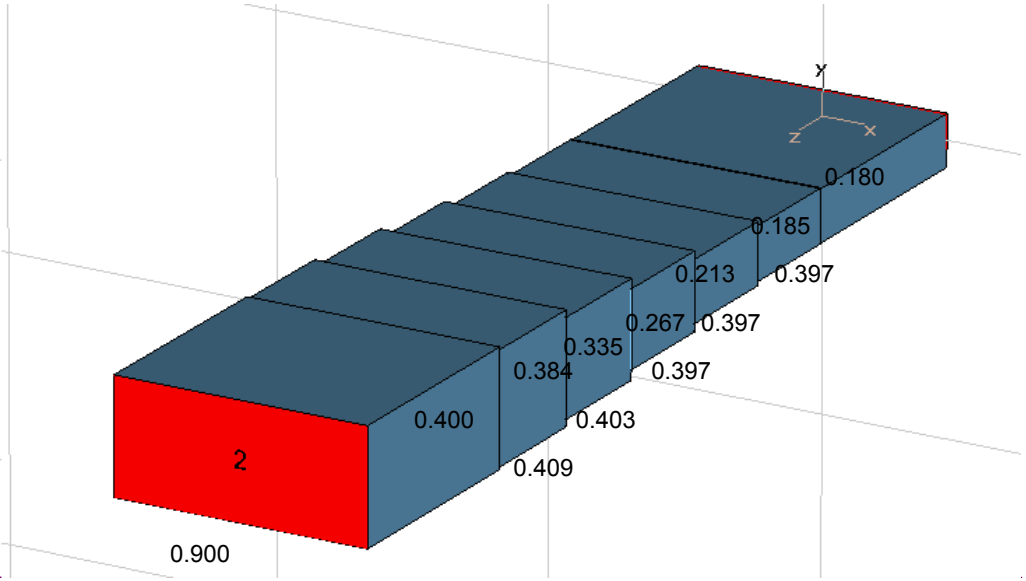


λ_g = 1.6133"; λ_g /4 = 0.4033

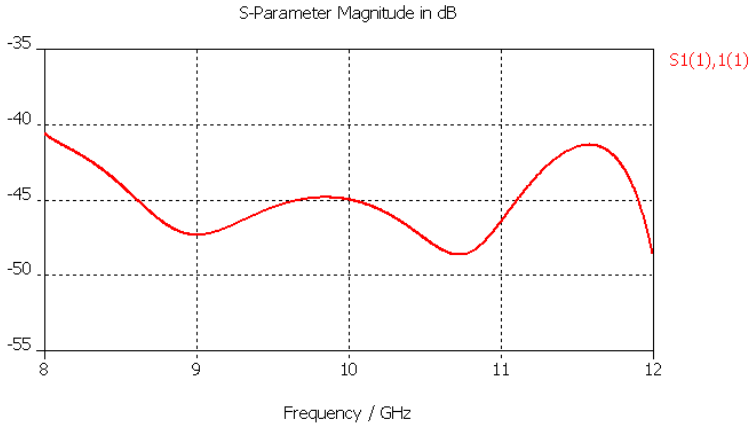


G. Matthaei, L. Young and E.M.T. Jones, "Length corrections for discontinuity capacitances", page 302

5-step Tchebyschev Transformer*



λ_g = 1.6133"; λ_g/4 = 0.4033



*Used this design

H-plane bend

$$|\rho| = \frac{\lambda_g^2}{32\pi^2 \mathcal{R}^2}\left[\sin\frac{2\pi\ell}{\lambda_g} - \frac{128}{\pi^2}\frac{a}{\lambda_g}B\cos\frac{2\pi\ell}{\lambda_g}\right]$$ ** (1)

where

$$B = \sum_{2,4}^{\infty} m^2\,(m^2-1)^{-3}\left[(m^2-1) - (2a/\lambda_g)^2\right]^{-0.5}$$ (2)

For a given |ρ| and λg, l is given by

$$\tan\frac{2\pi l}{\lambda_g} = \frac{128}{\pi^2}\frac{a}{\lambda_g}B$$ (3)

a=0.900 and λg=1.6133
l=0.105λ_g or l=[0.105+(n/2)] λ_g
For n=3, l=2.589; R=1.648

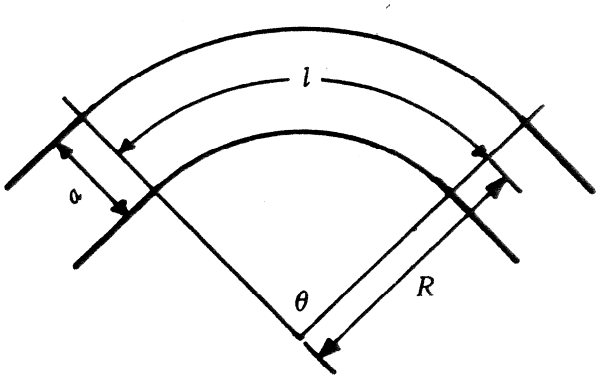
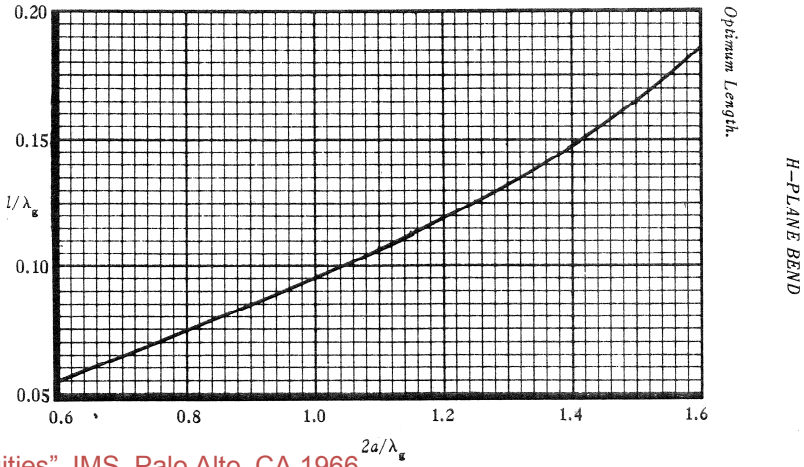


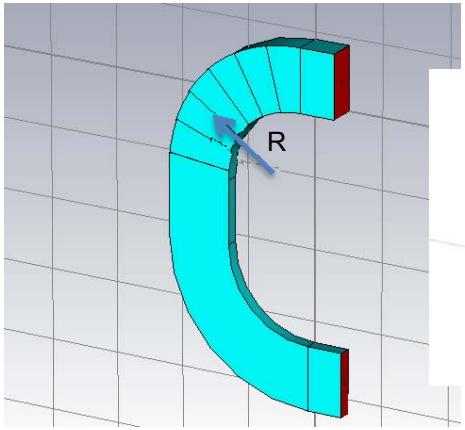
FIG. 10. – CONSTANT RADIUS H-PLANE BEND.

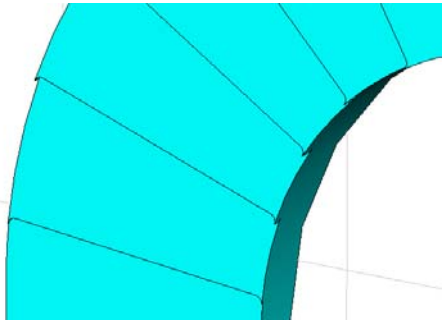


** F.C. de Ronde, "Full Band Matching of Waveguide Discontinuities", IMS, Palo Alto, CA 1966

W.B.W. Alison, *A Handbook For The Mechanical Tolerance of Waveguide Components*, Artech House, 1972

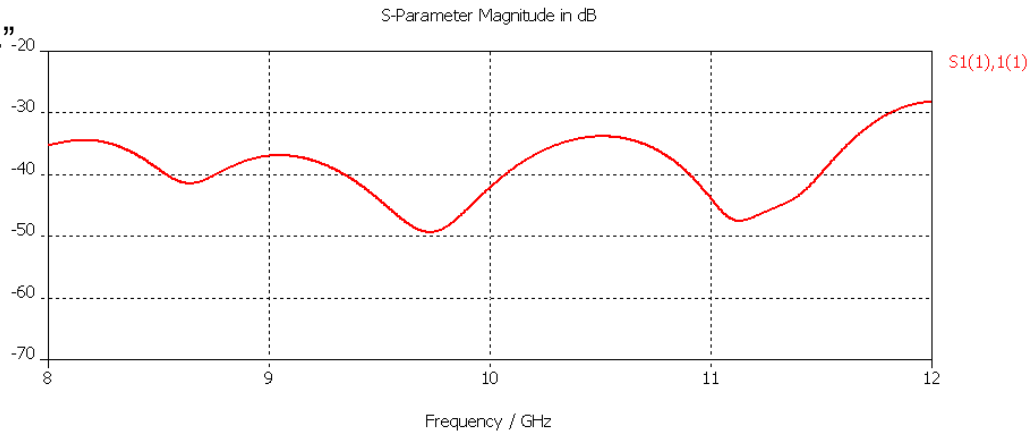
H-plane bend with stepped transformer



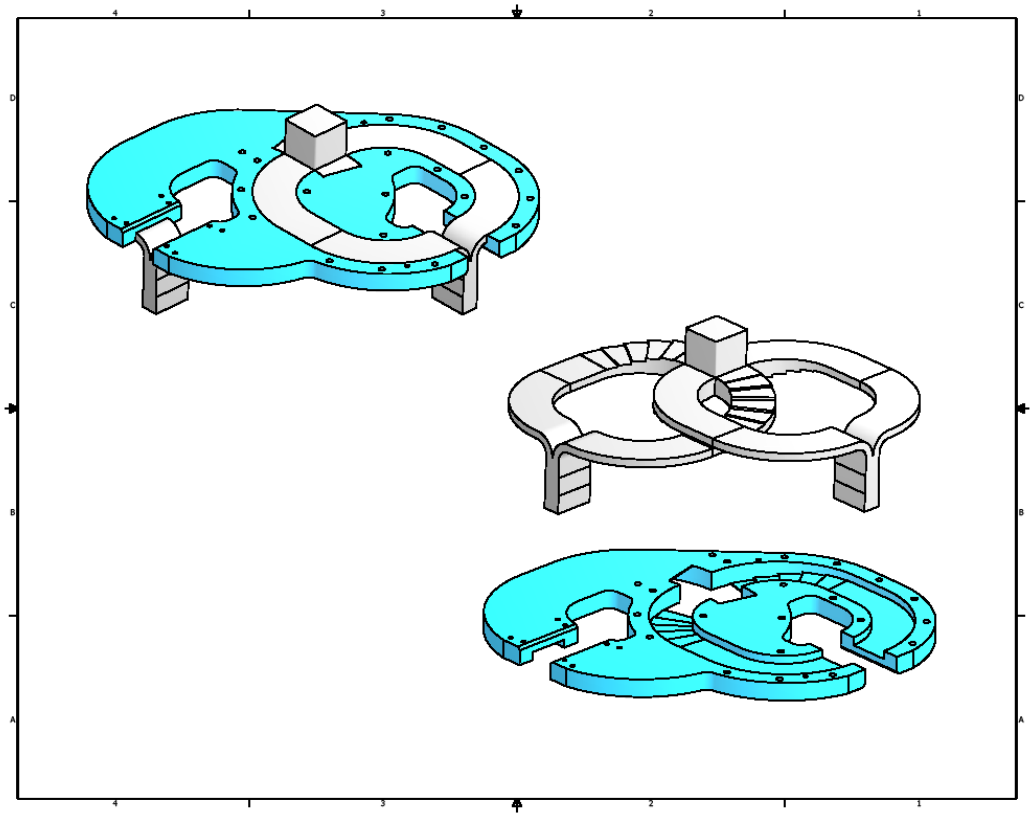


Cutting tool
Radius=0.0235
Length=0.470

R x π/2 = l
l = 1.605 λ_g ; R=1.6484”

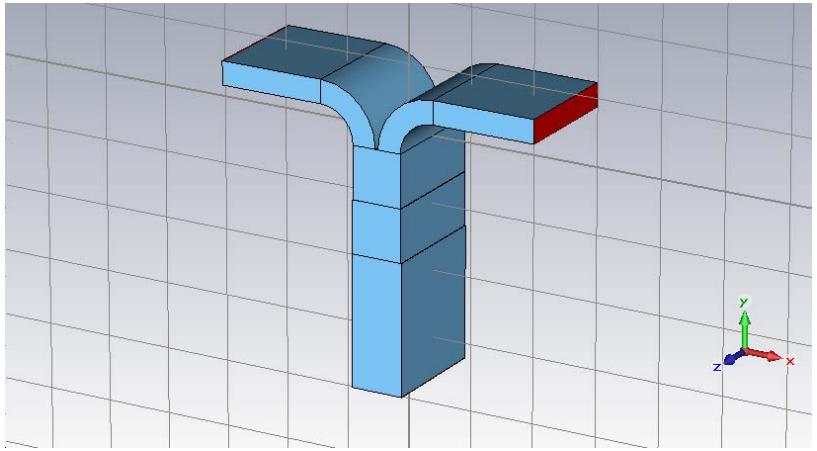


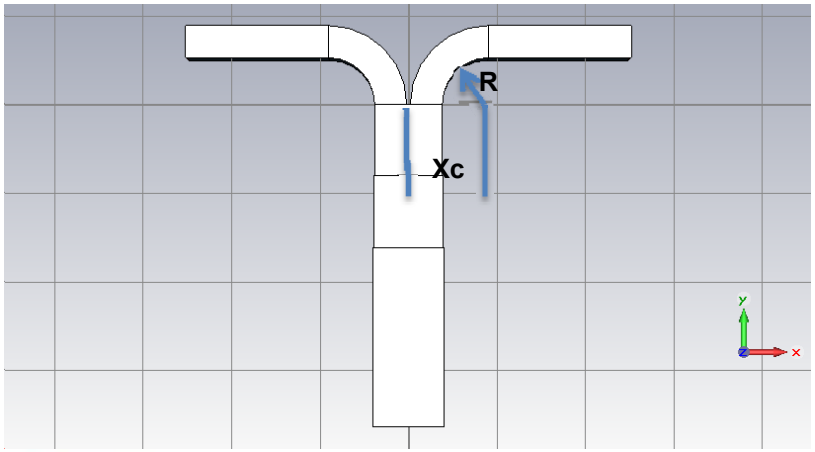
E-plane Y-Junction

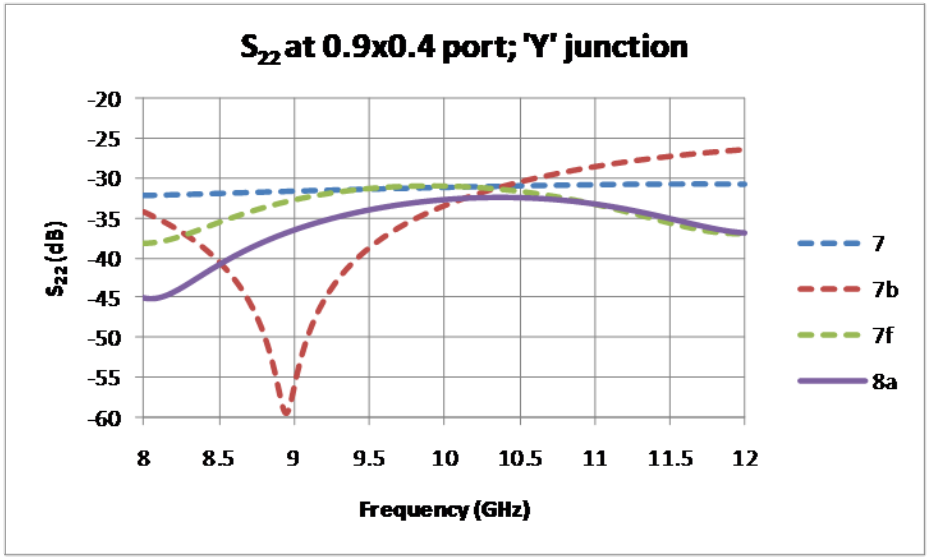


Y-junction
Input: 0.900x0.180
Output: 0.900x0.380
0.900x0.390
0.900x0.400

E-plane Y-junction



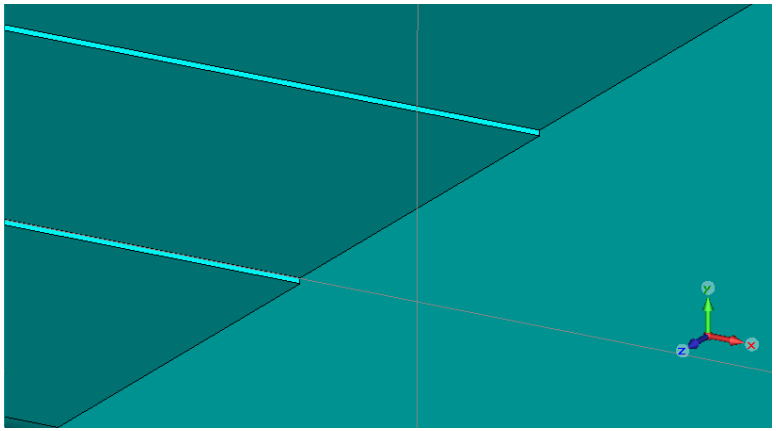


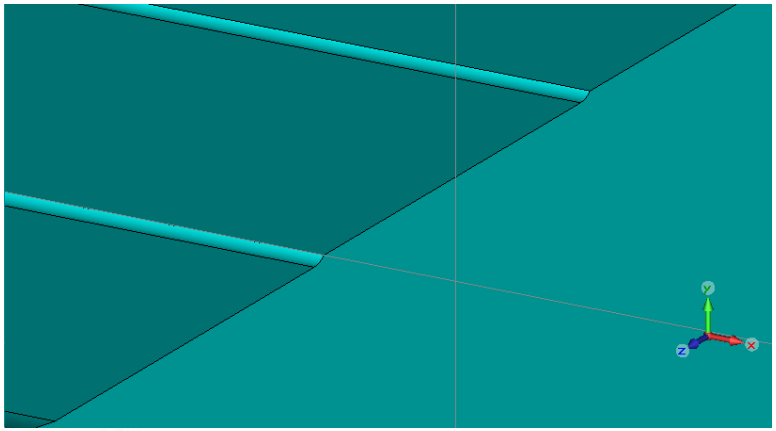


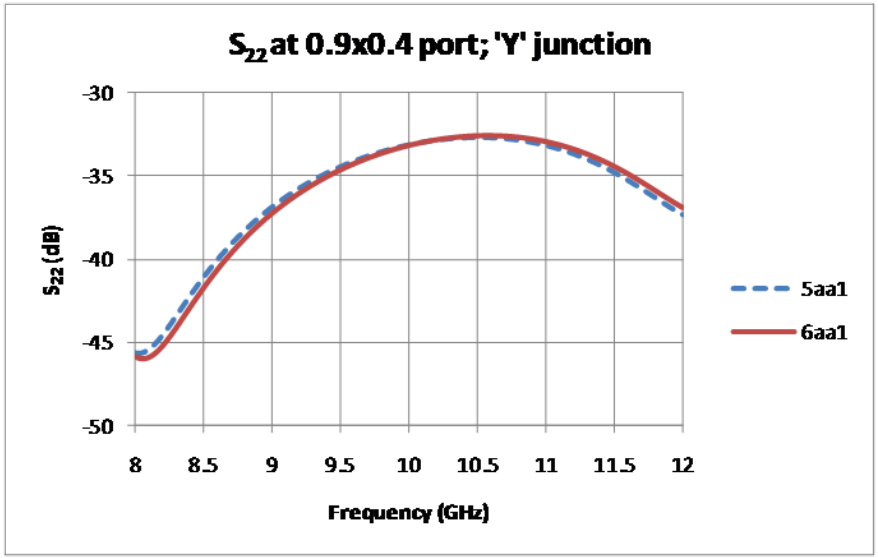
	R	Xc	
7	0.450	0.640	
7b	0.450	0.640	0.380 to 0.400
7f	0.450	0.640	0.380, 0.390, 0.400
8a	0.260	0.450	0.380, 0.390, 0.400

$S_{11} \leq -32.6$

E-plane Y-junction

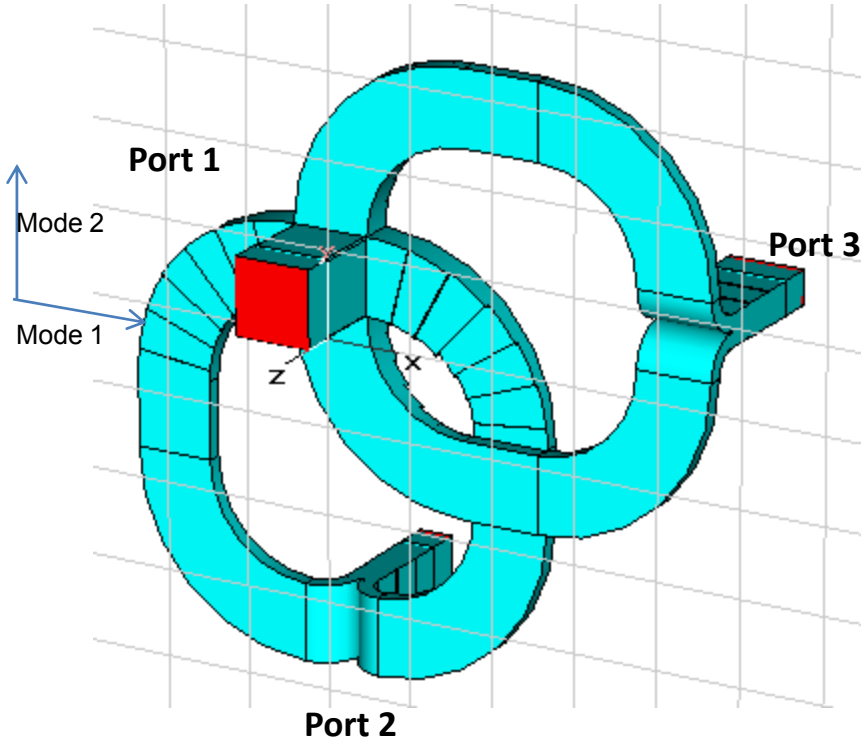


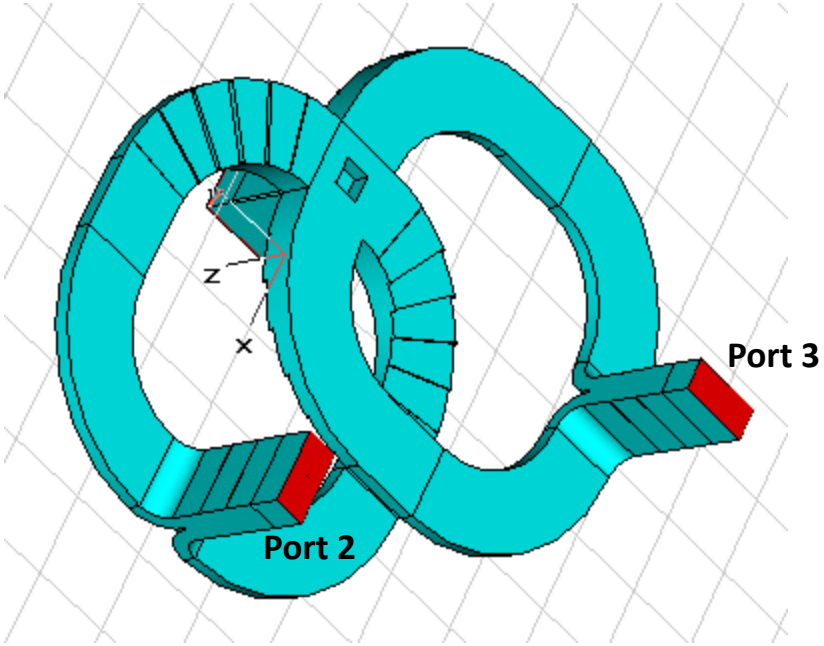




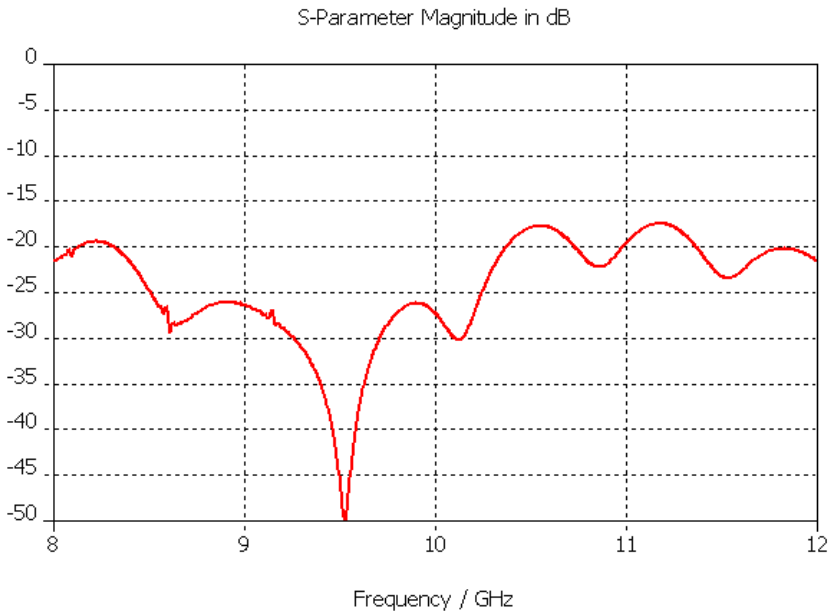
5aa1: No radius on steps
6aa1: 0.0235 radius
$S_{11} \leq -32.6$

CST Microwave Studio Model

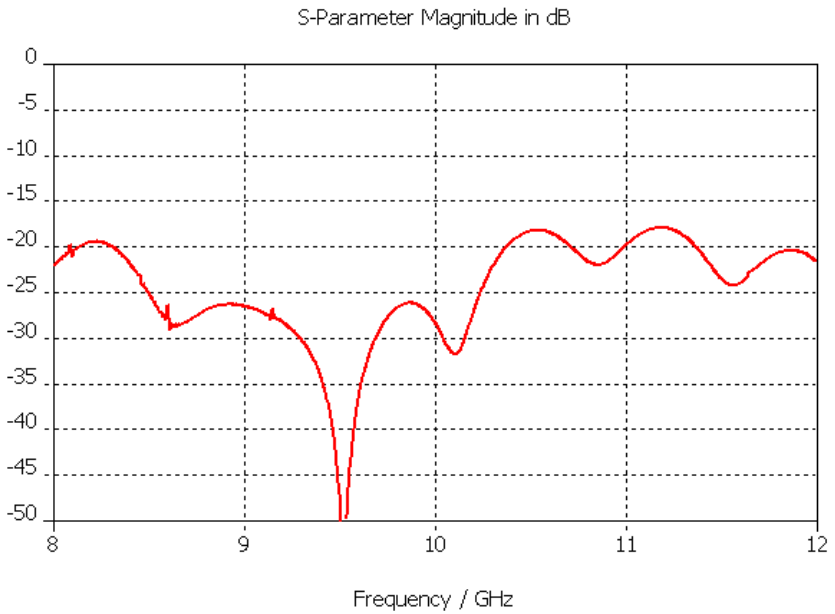




Input Return Loss



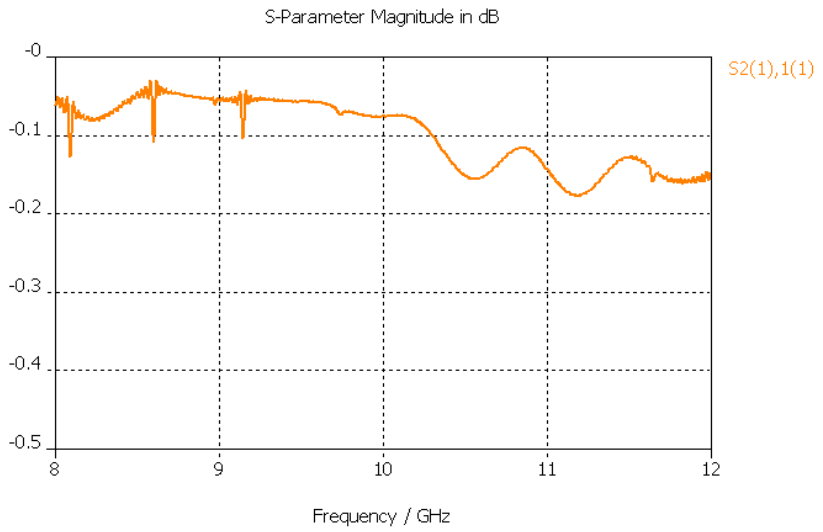
S1(1),1(1)



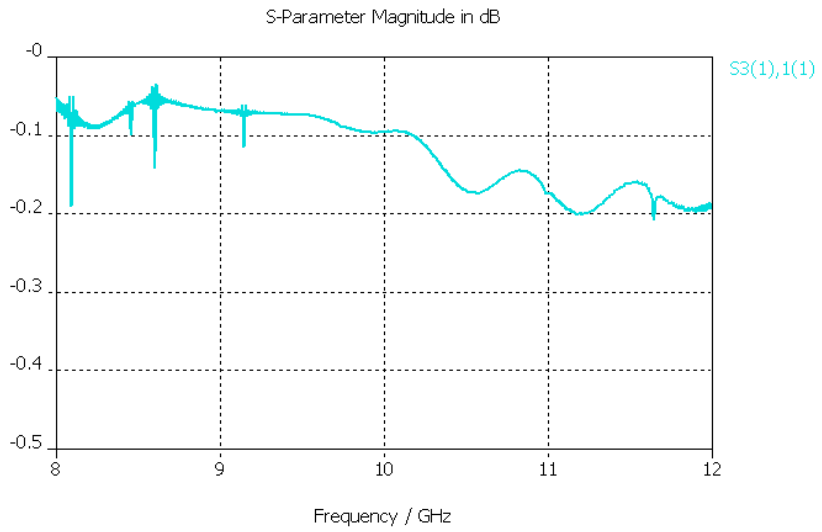
S1(2),1(2)

S_{11}<-17.4 dB

Insertion Loss

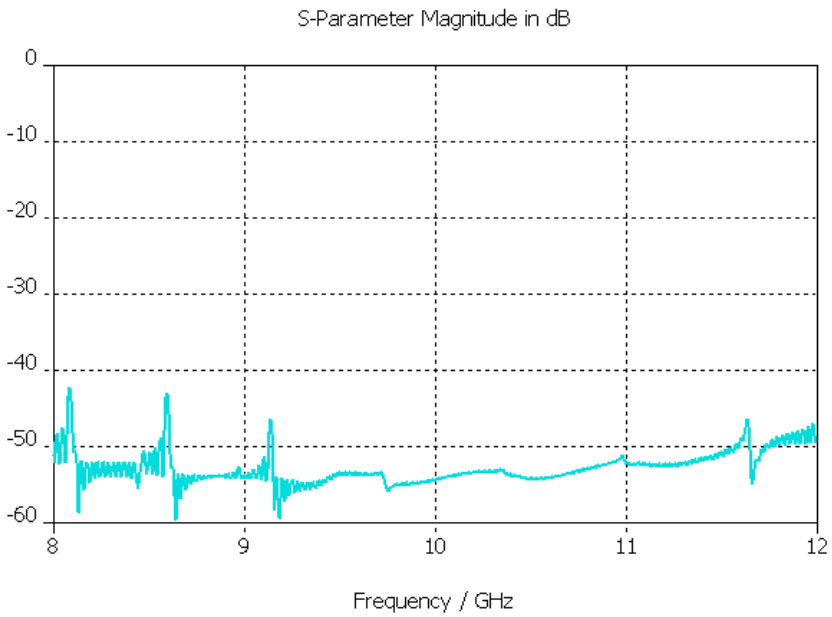


S2(1),1(1)

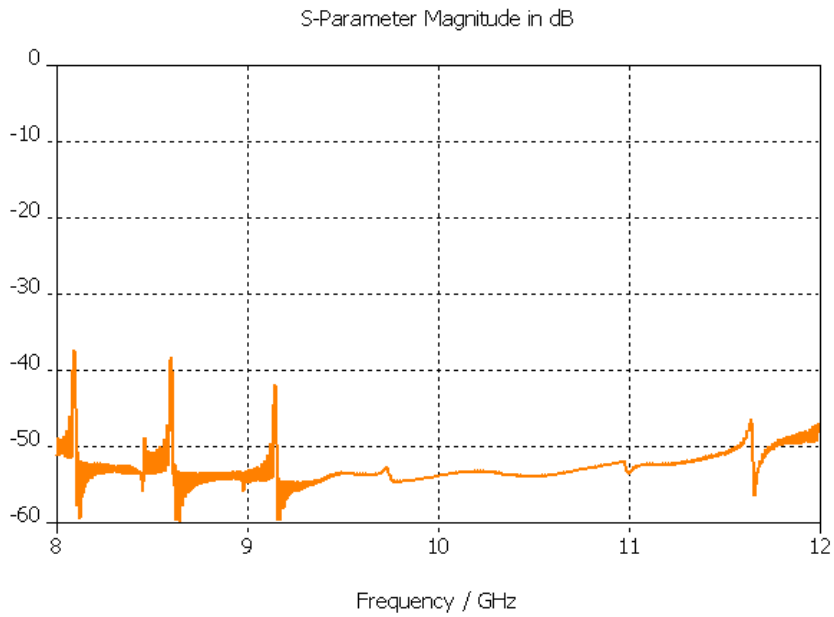


S3(1),1(2)

Crosspolarization

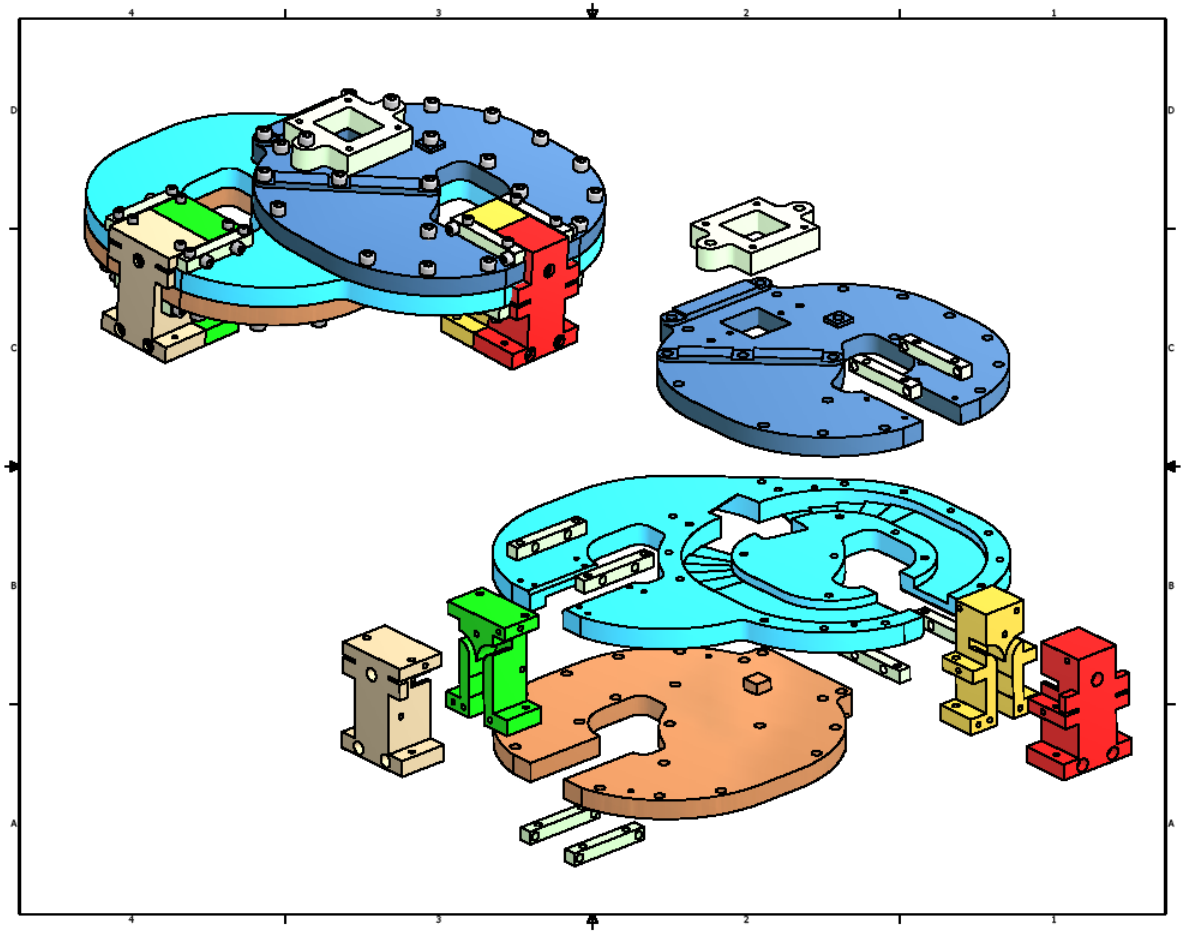


S3(1),1(1)



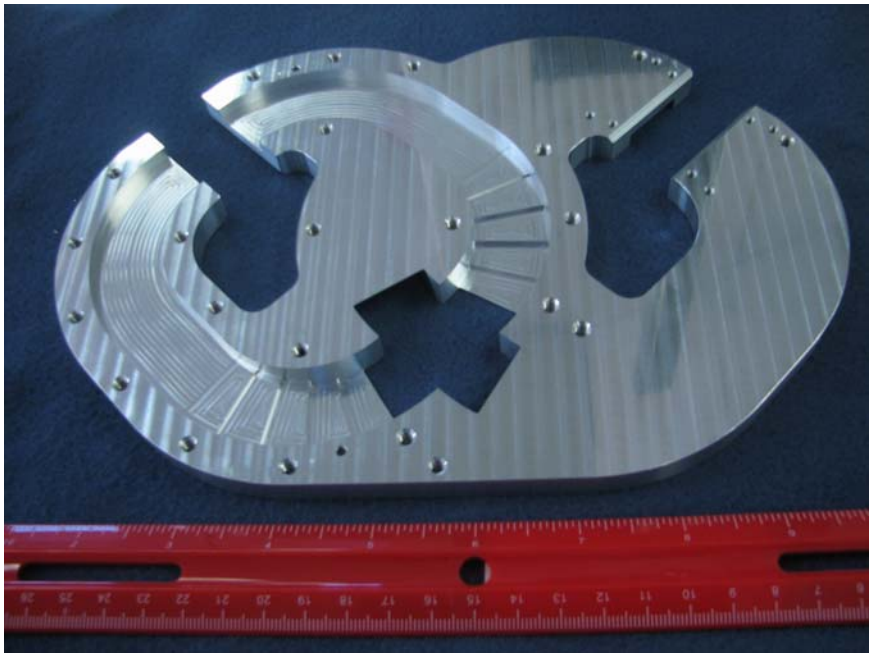
S2(1),1(2)

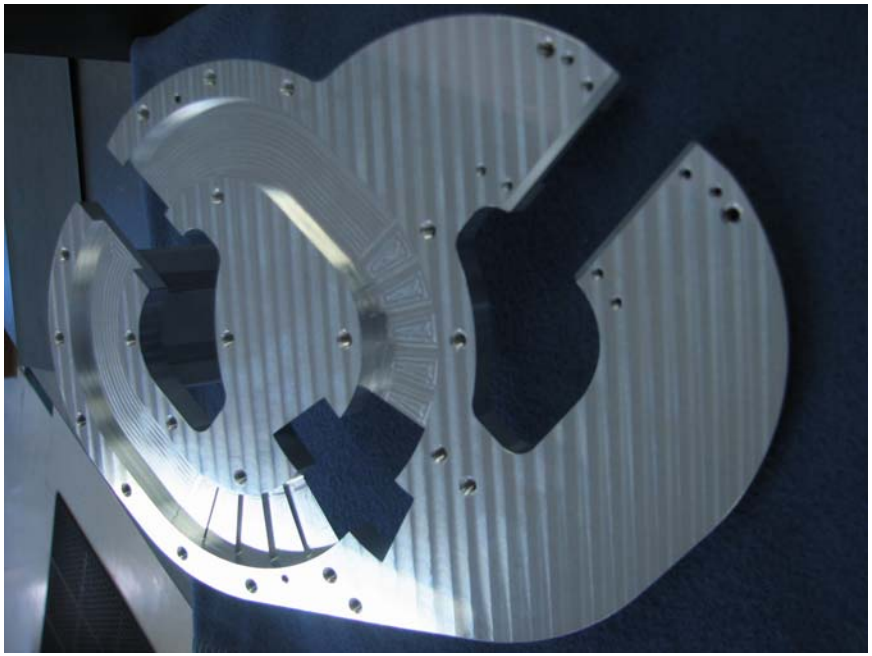
Mechanical Design



Cross-section 9.25”; Height 2.68”; Measured weight : 4.4 lbs

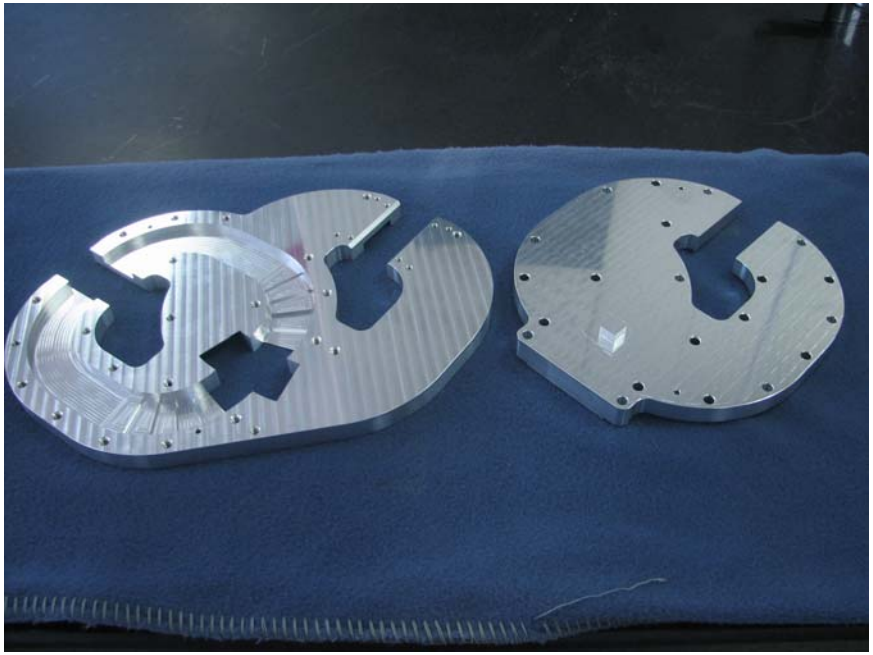
Center plate with curved stepped transitions



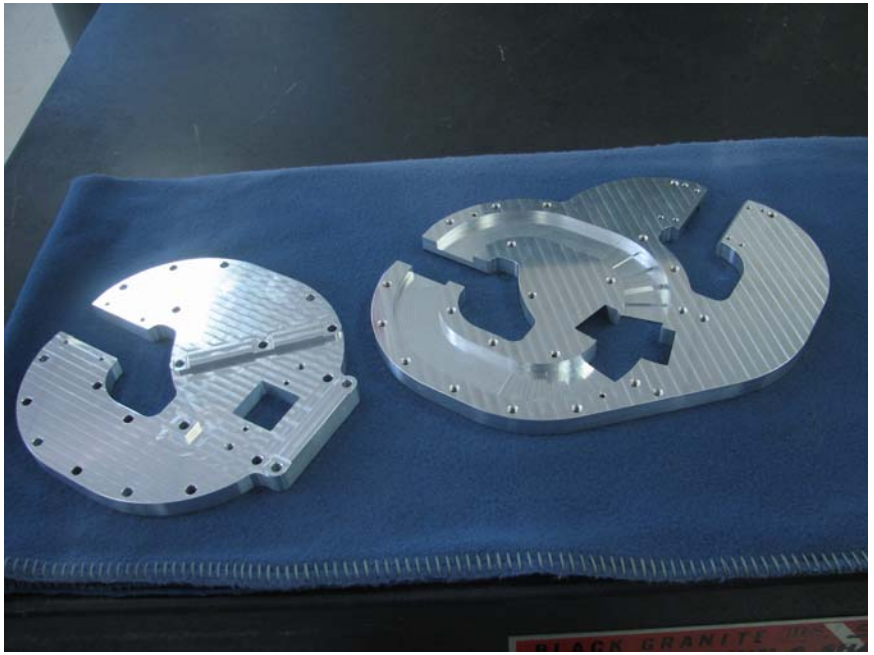


Side arms with bends and stepped transformer

Bottom and top plates

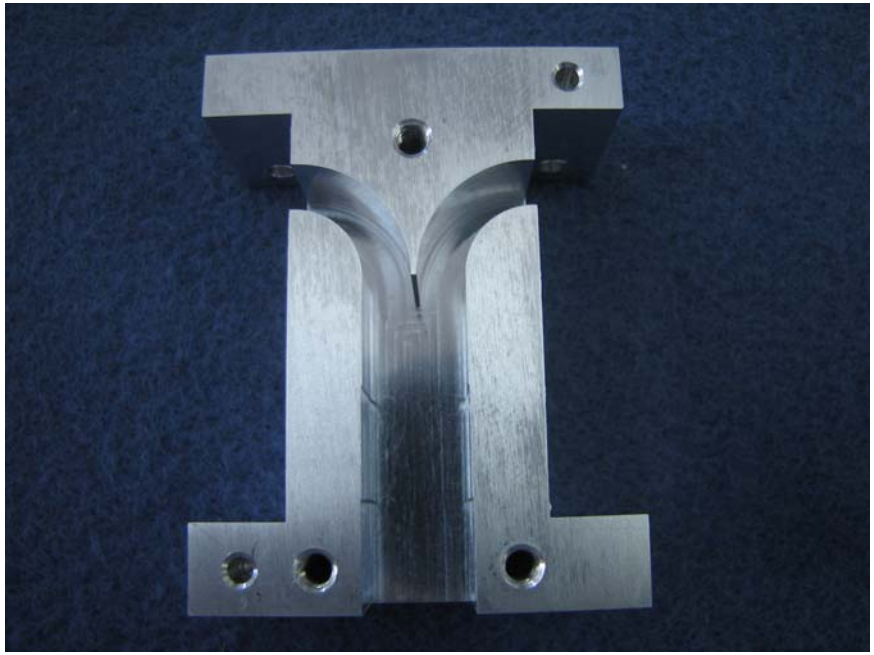


Bottom plate with square tuning stub

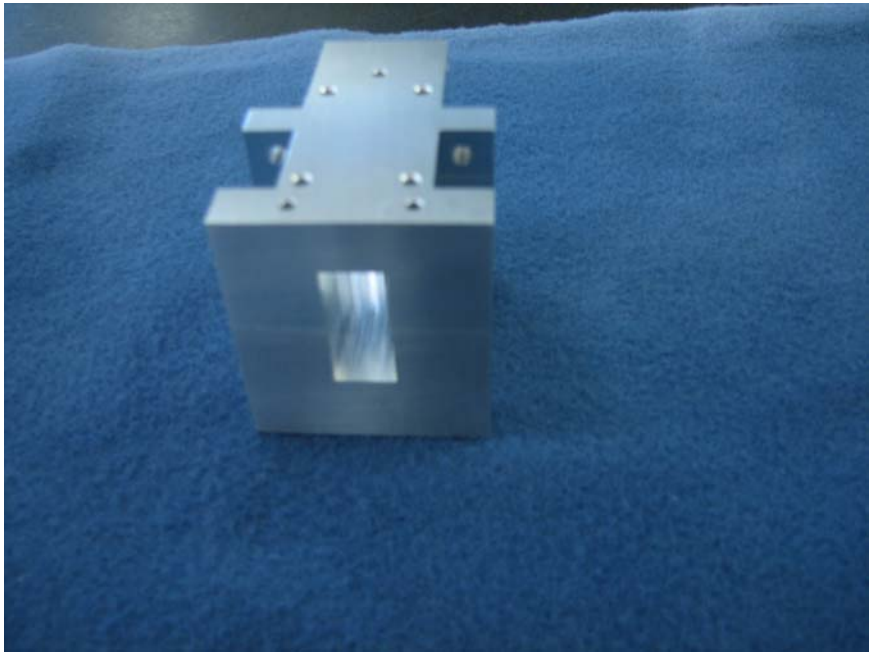


Top plate with input waveguide

E-plane Y-Junction



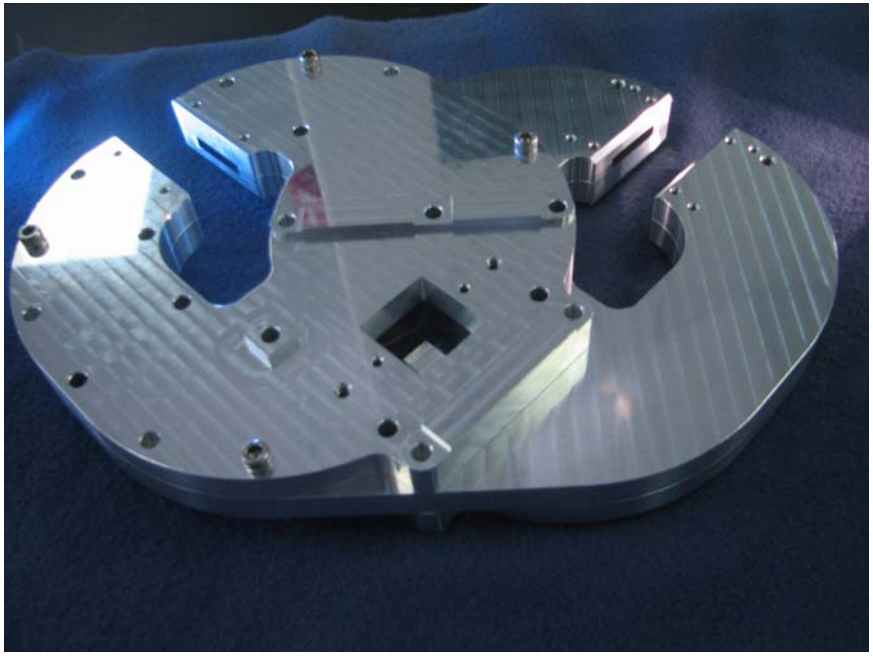
E-plane split block



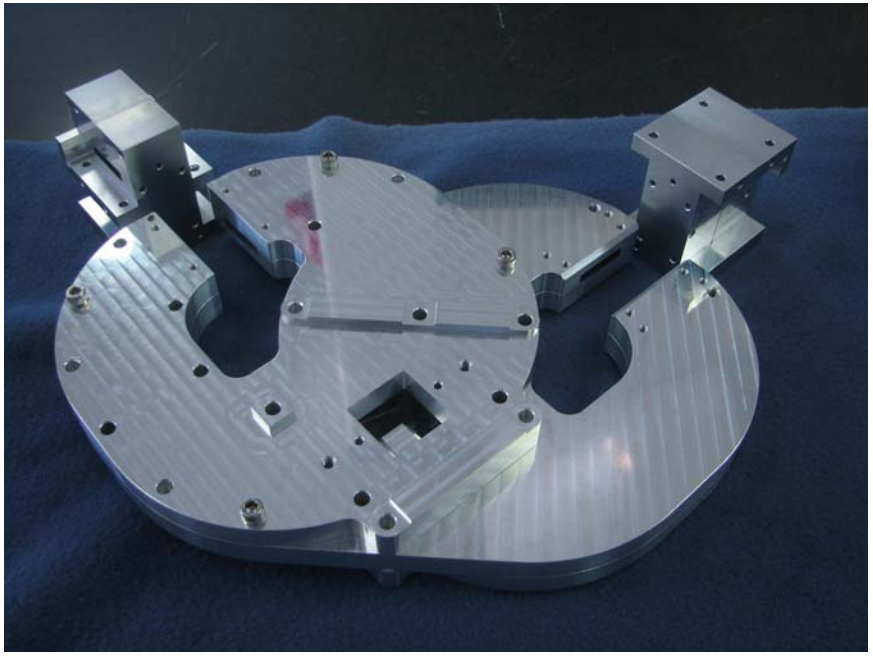
Assembled Y-Junction

Input 0.900x0.180; Output at junction 0.900x0.380
Inner radius 0.260; Outer radius 0.440; Center 0.450

Assembly

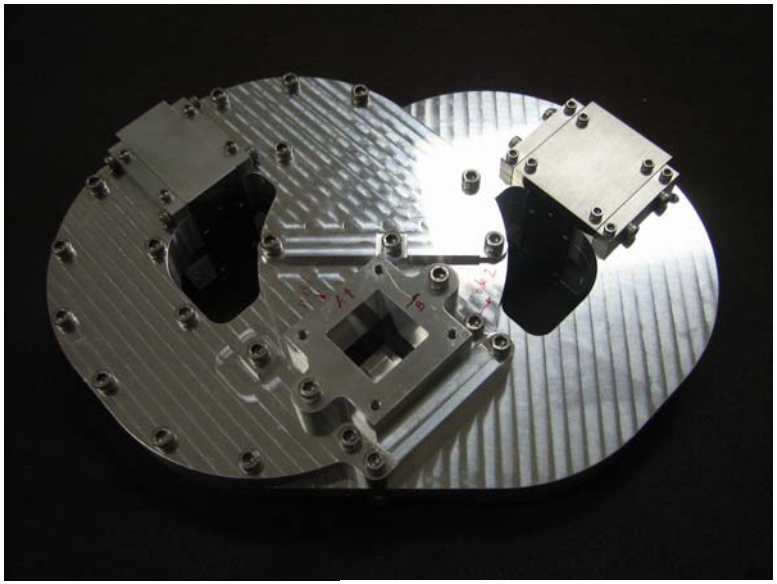


Main body assembled

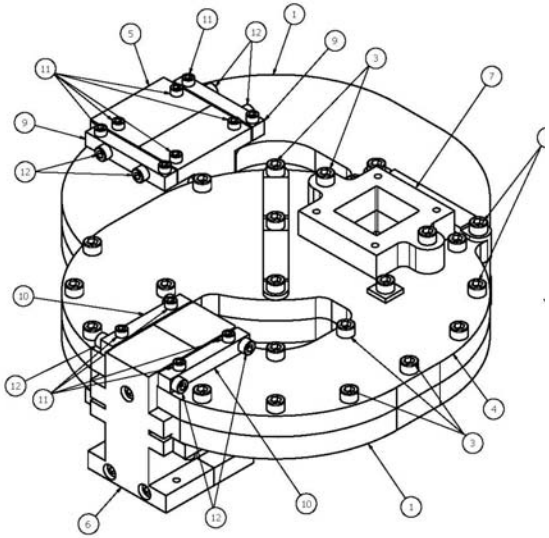


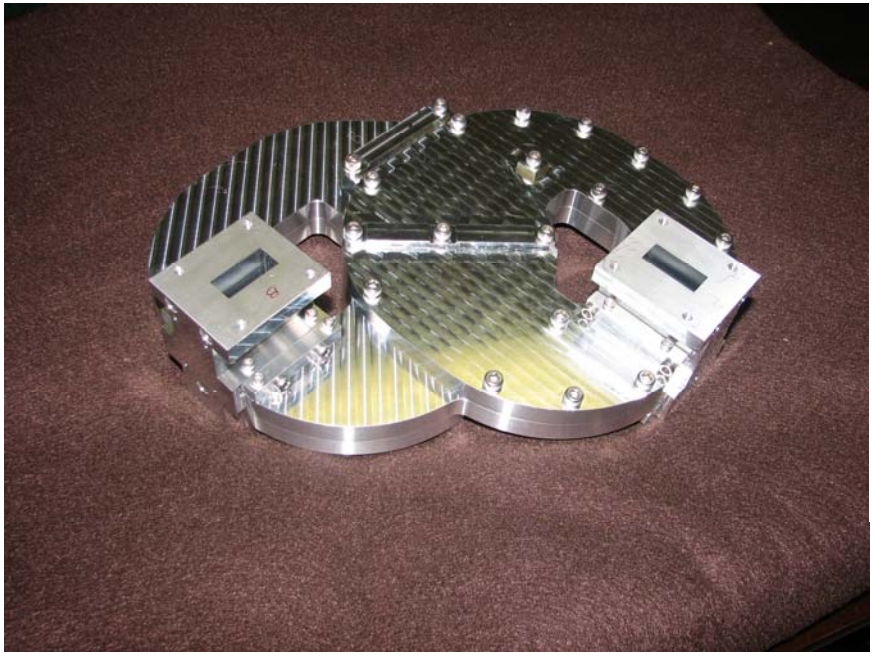
Main body, output ports

Assembled OMT



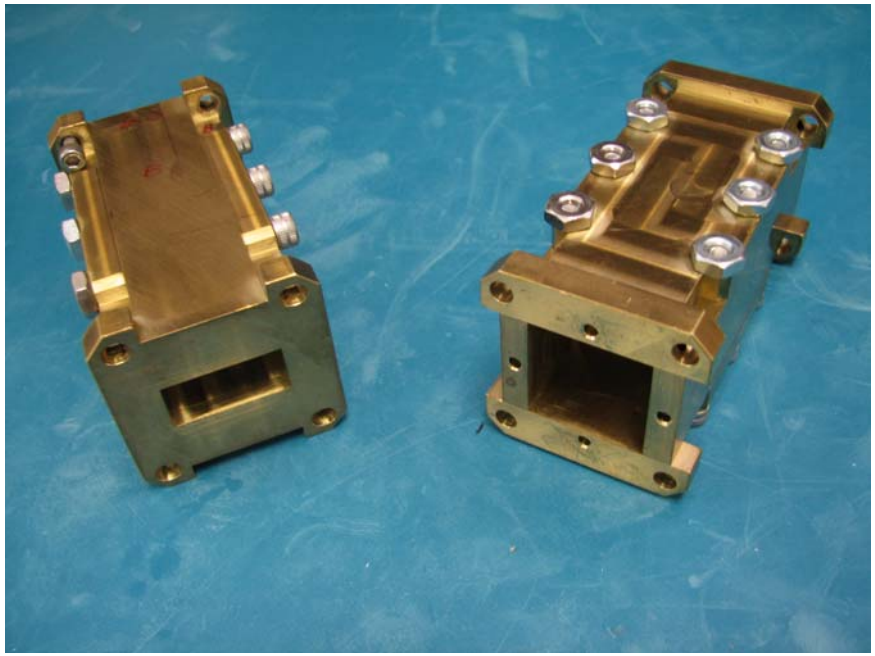
Square port

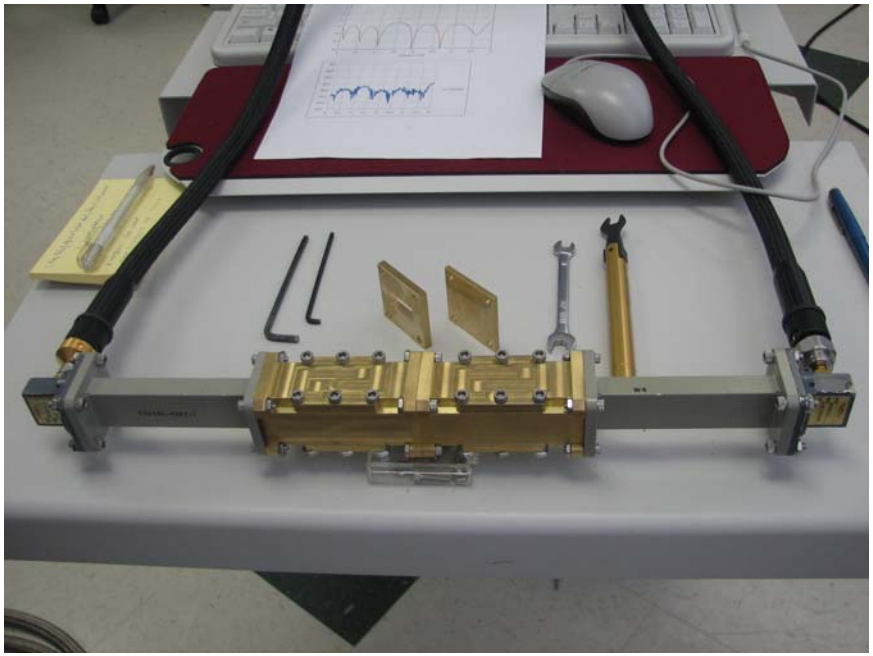




Rectangular ports

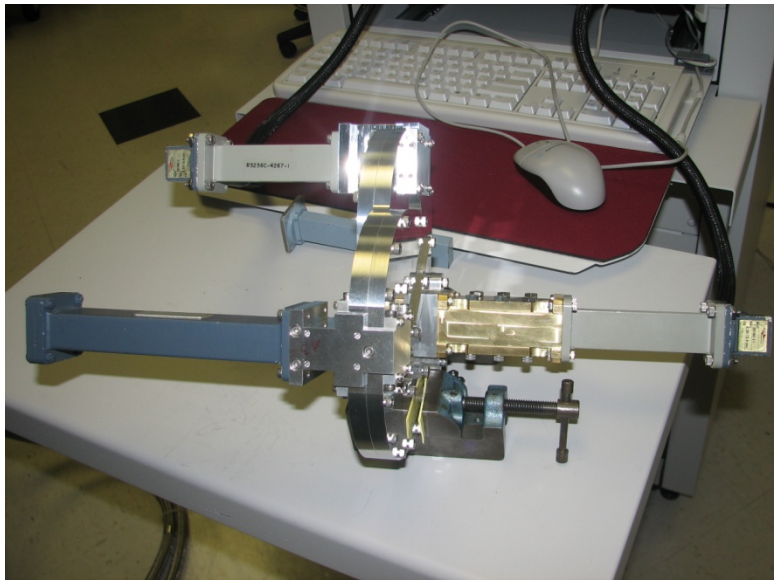
Measurement

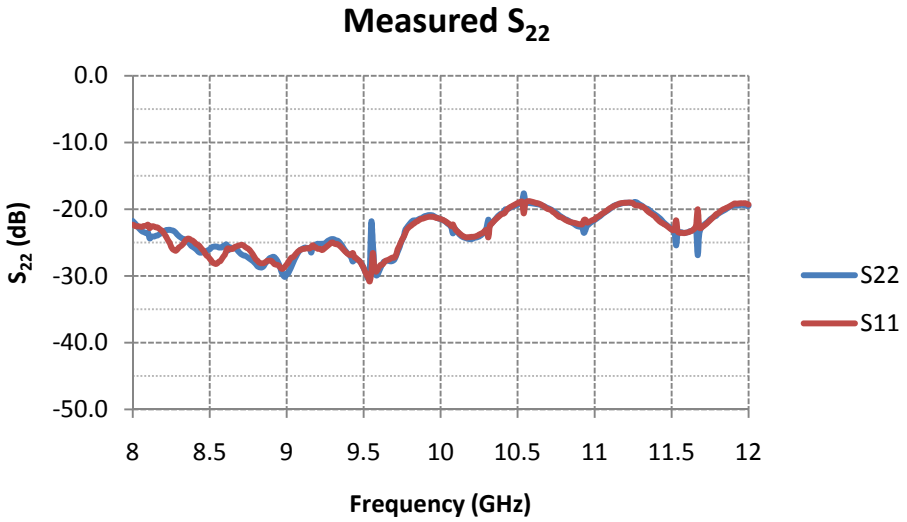




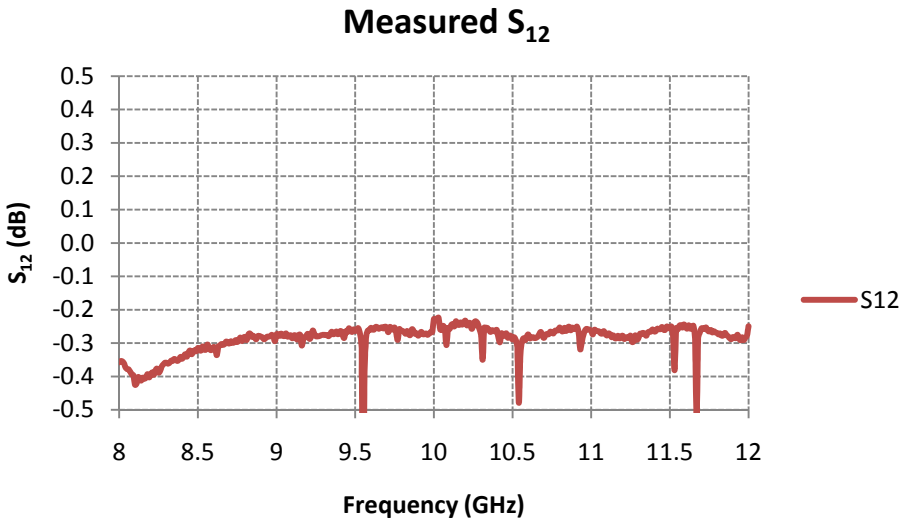
Measurements with Agilent N5245A PNA-X

S_{22} and S_{12}-Port 2

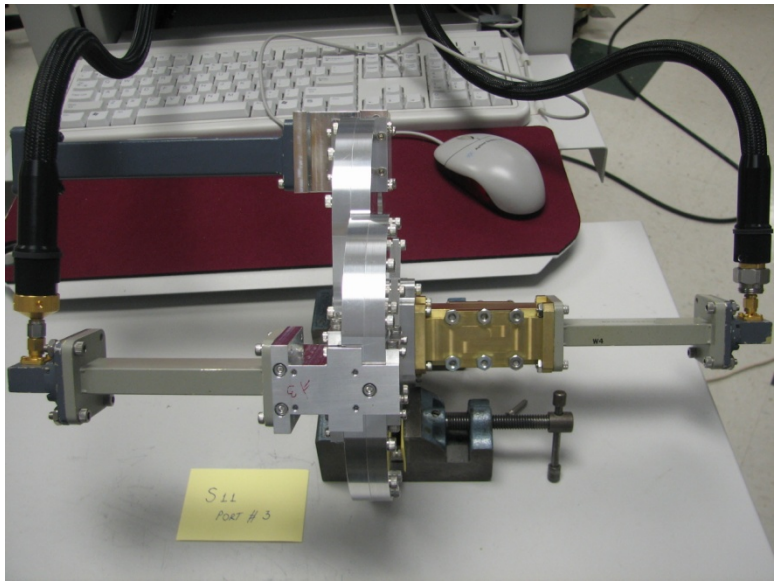


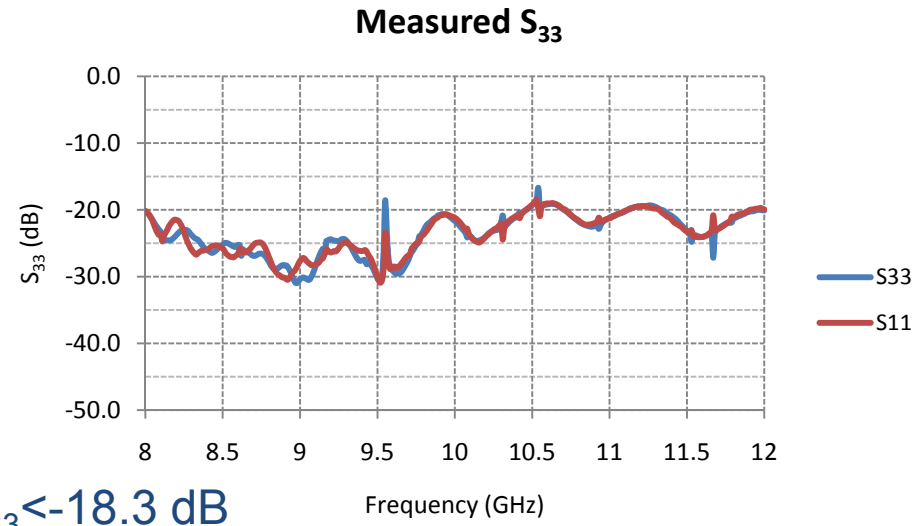


S_{22}<-18.7 dB

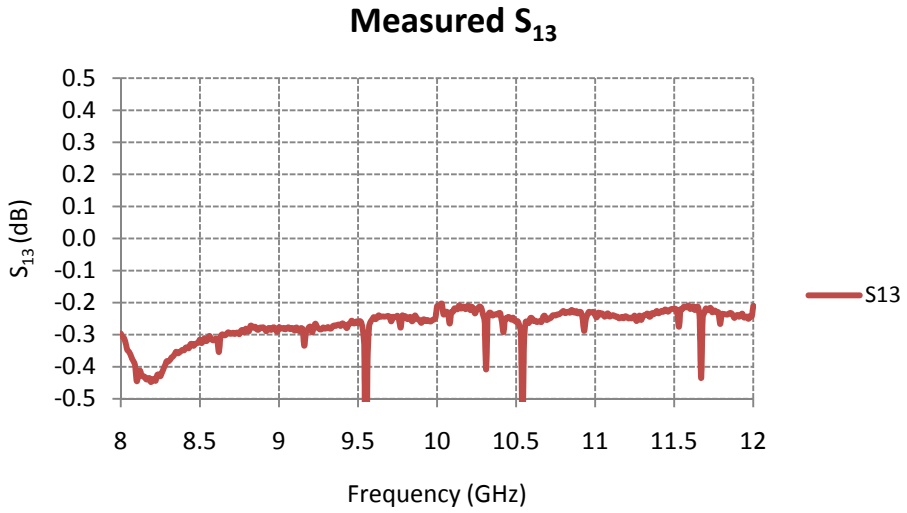


S_{33} and S_{13}-Port 3

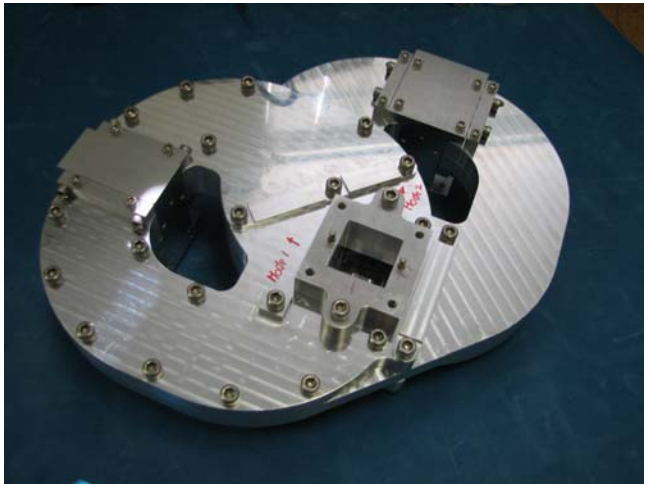


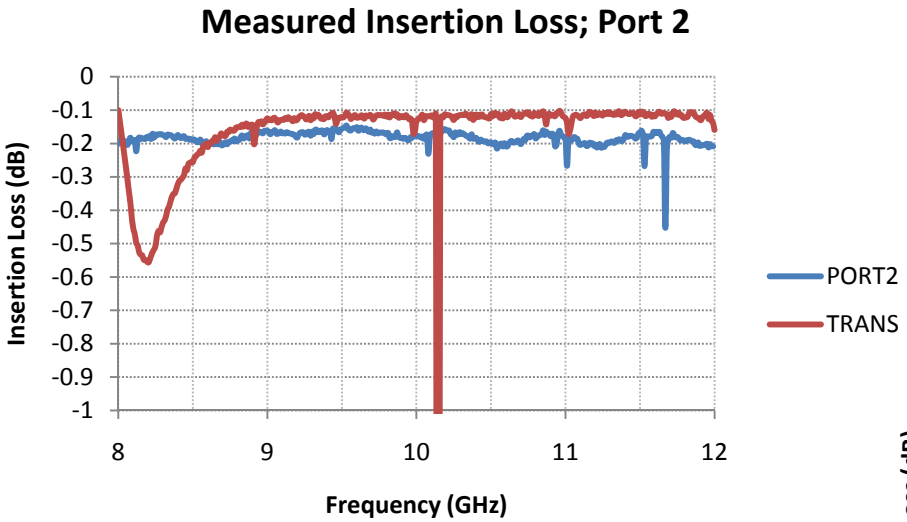


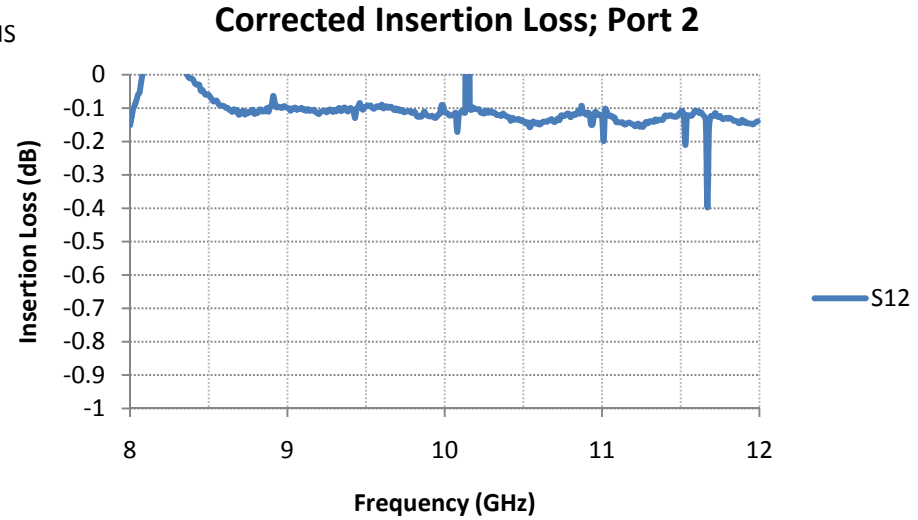
S_{33}<-18.3 dB



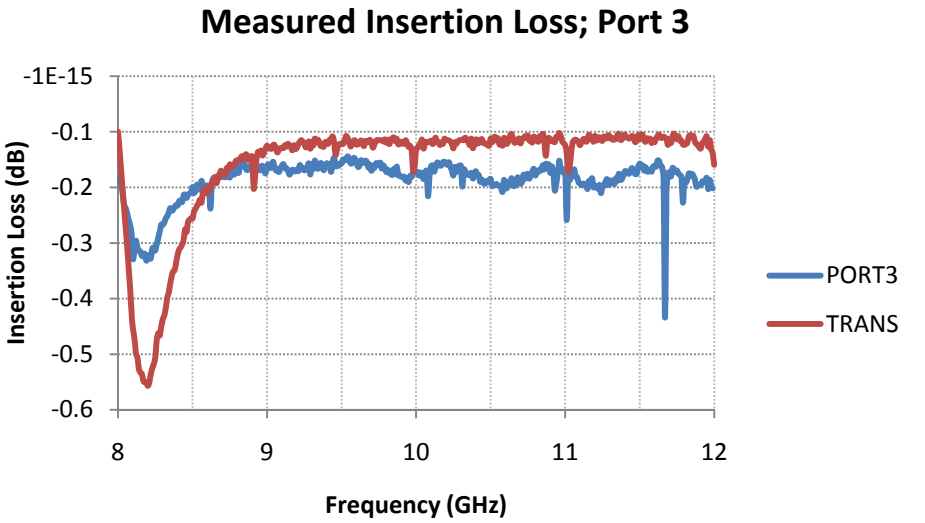
Measurement of S_{12} after pinning

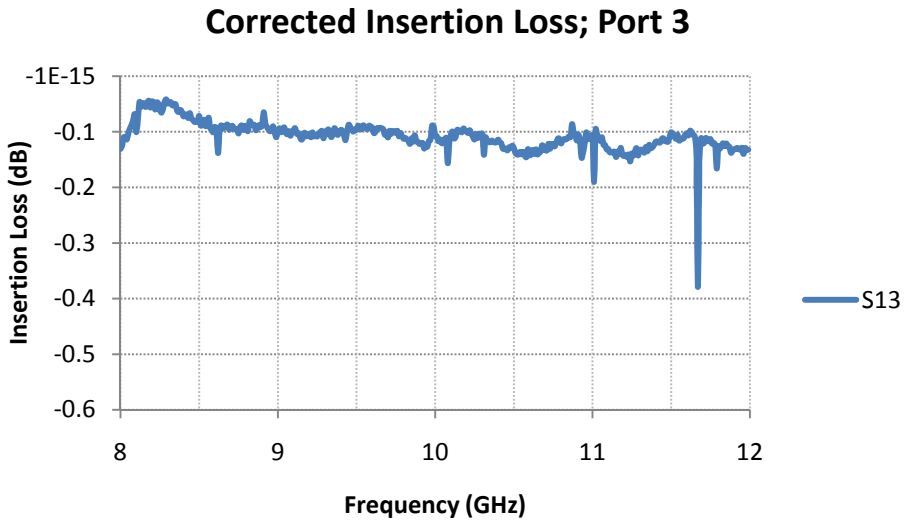




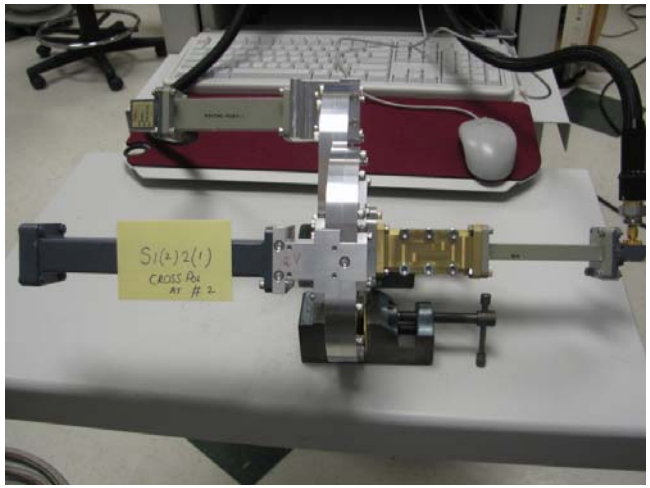


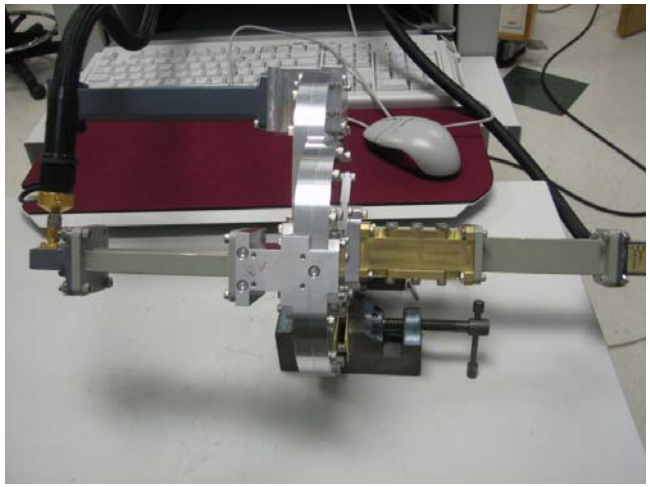
Measurement of S_{13} after pinning

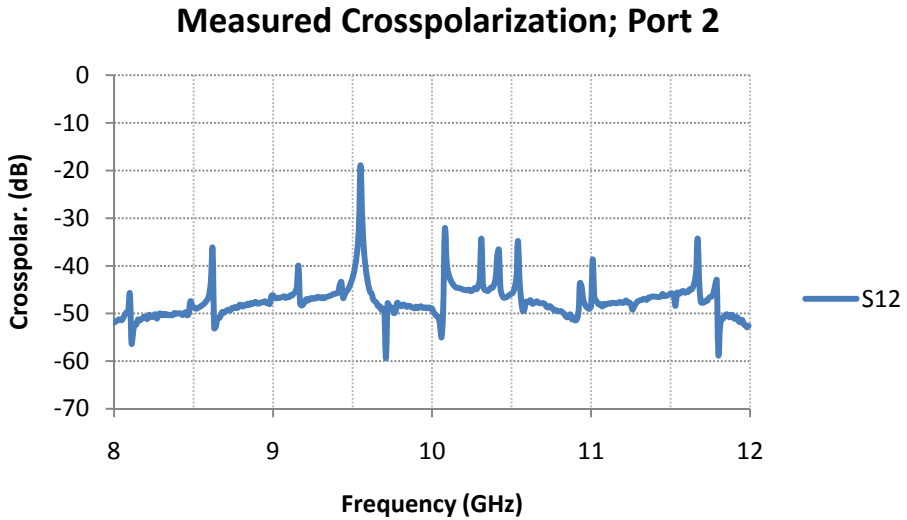


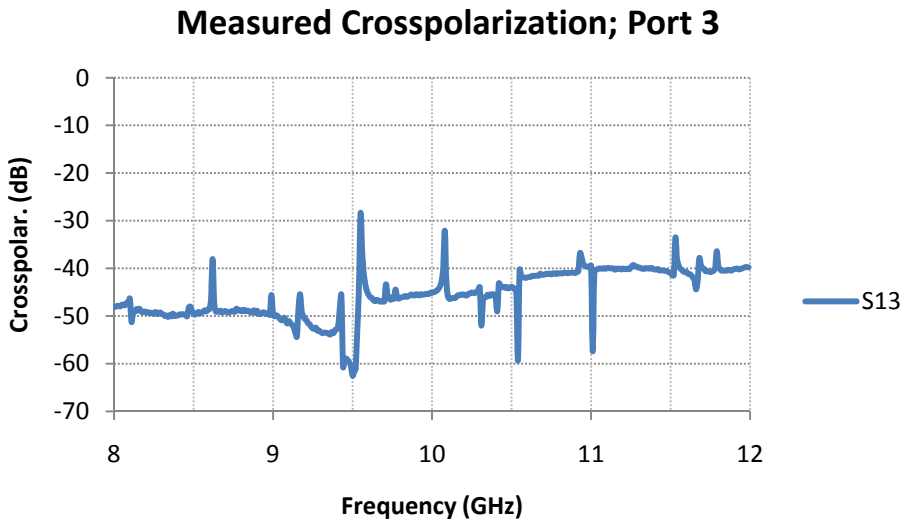


Crosspolarization

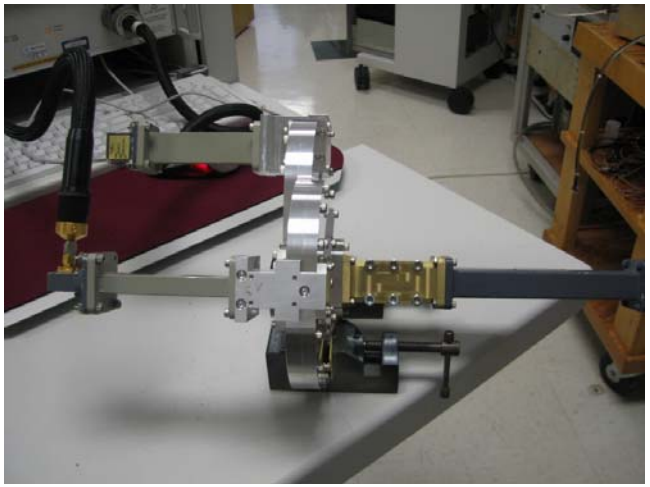


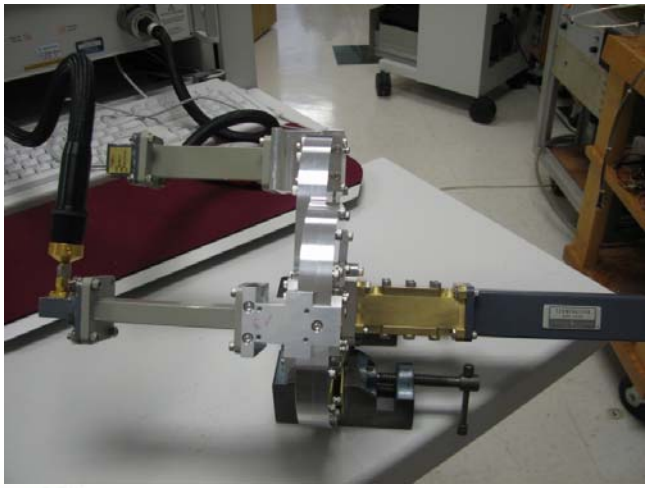


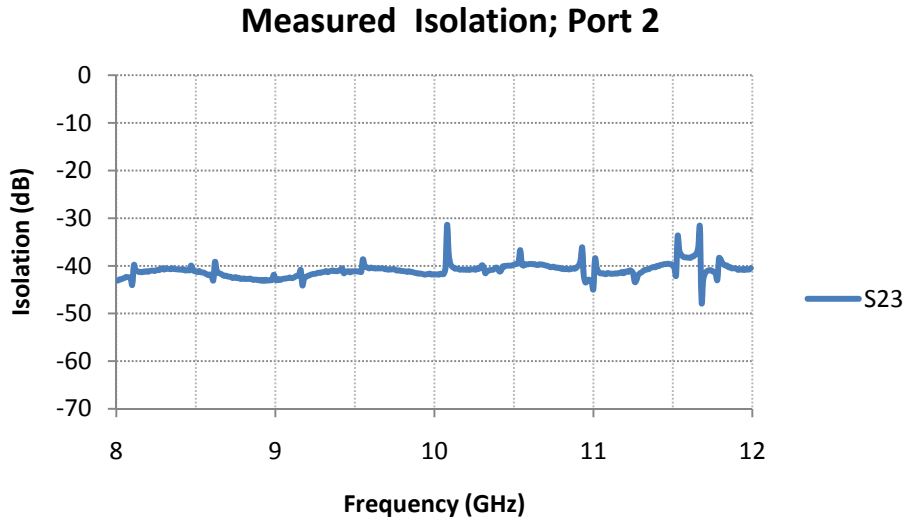


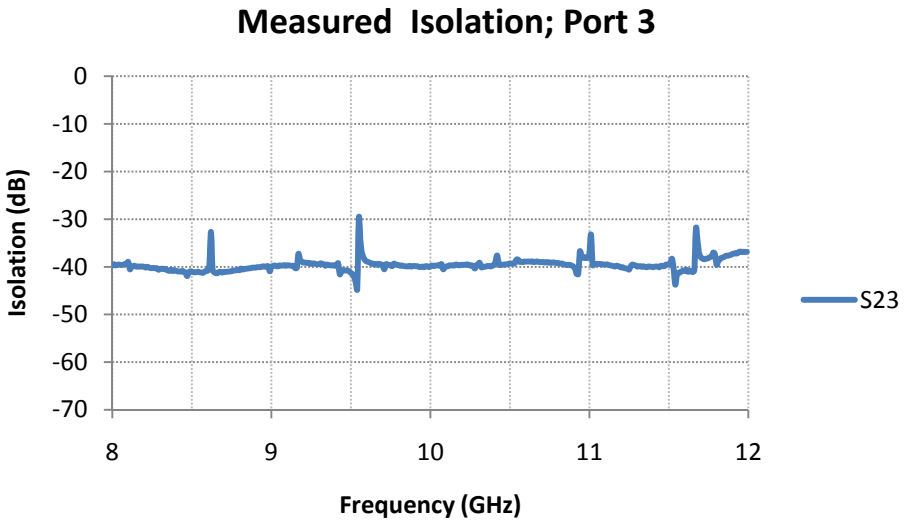


Isolation between ports

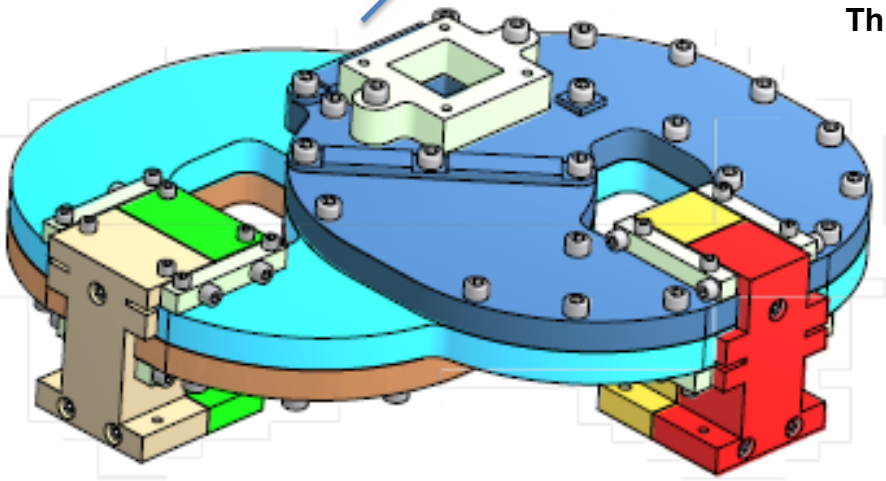




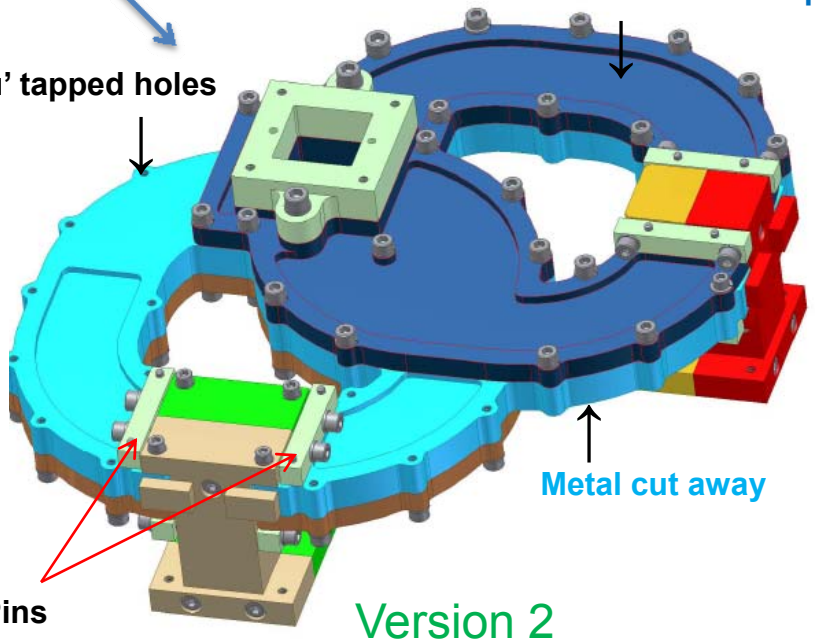




Jillian Michaels Weight Loss Program

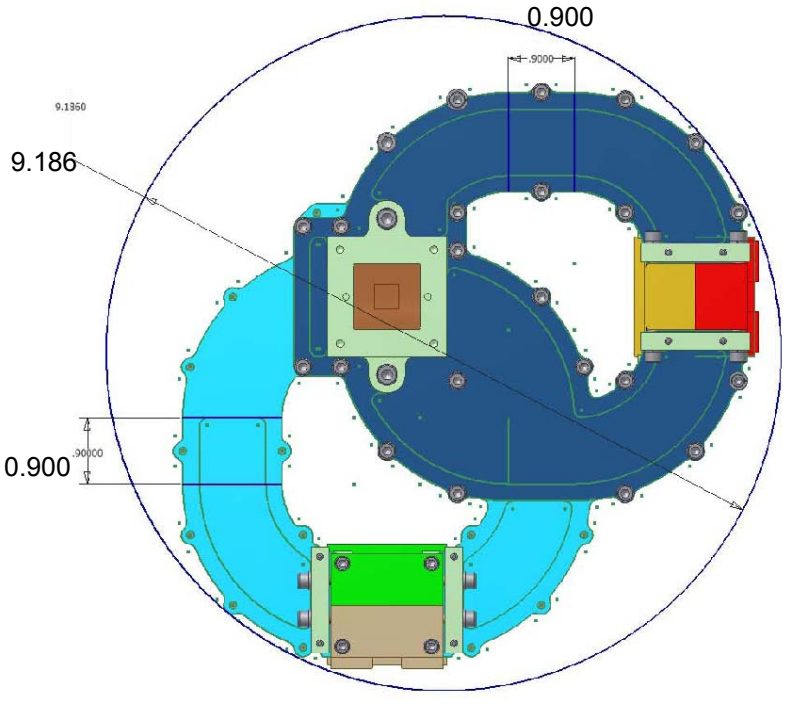


Version 1
Weight: 4.39lbs
Dia 9.25”; Ht 2.68”

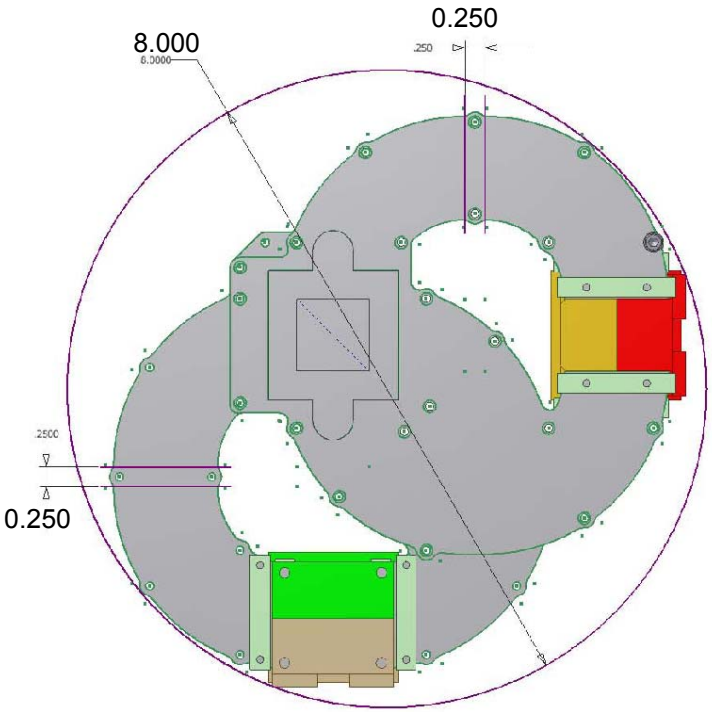


Version 2
Weight: 2.55lbs
Dia 9.18”; Ht 2.68”

More compact design

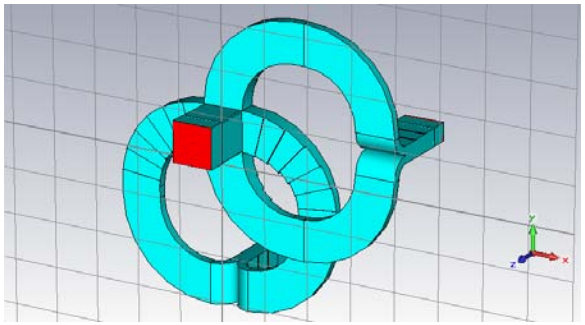


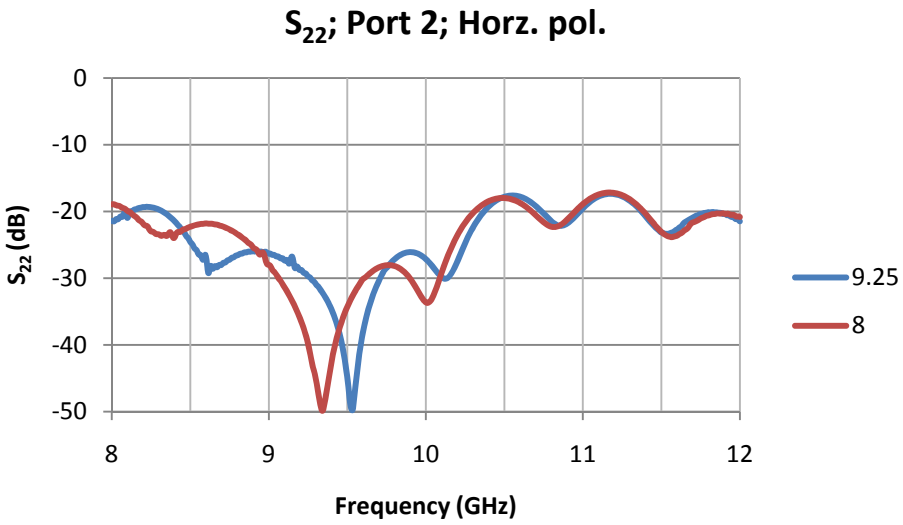
Version 2: 2.55 lbs

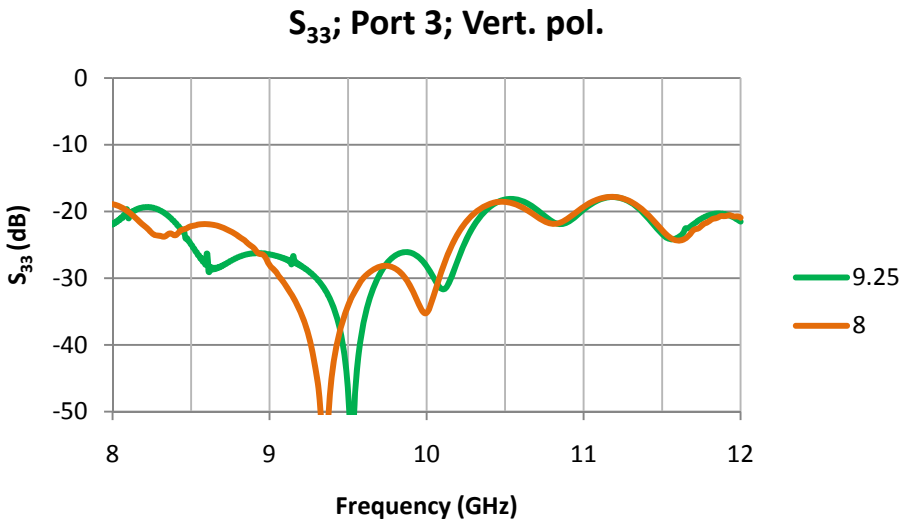


Version 3: 2.2 lbs

Performance of 9.25” & 8.0” OMTs (CST)

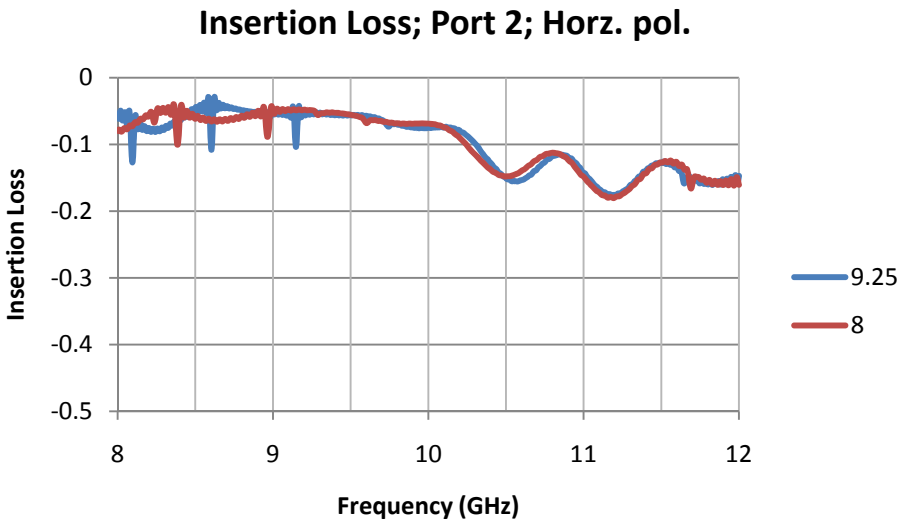


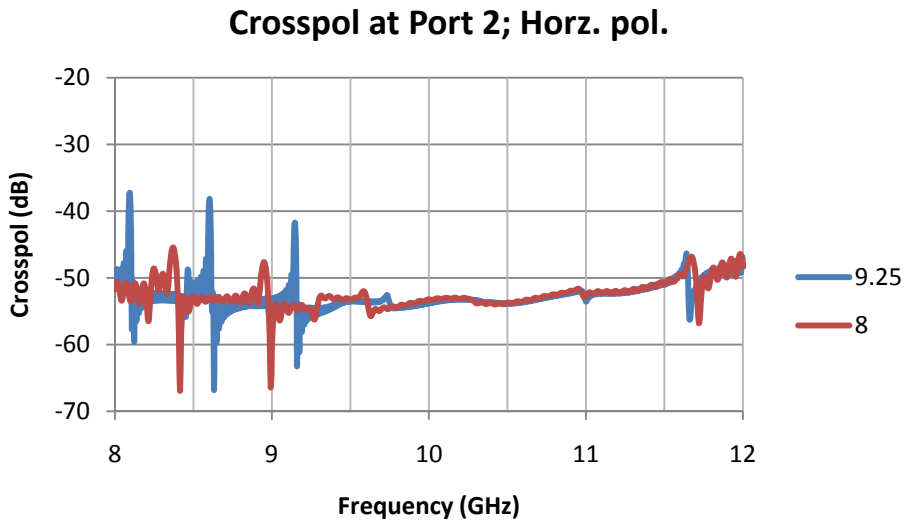




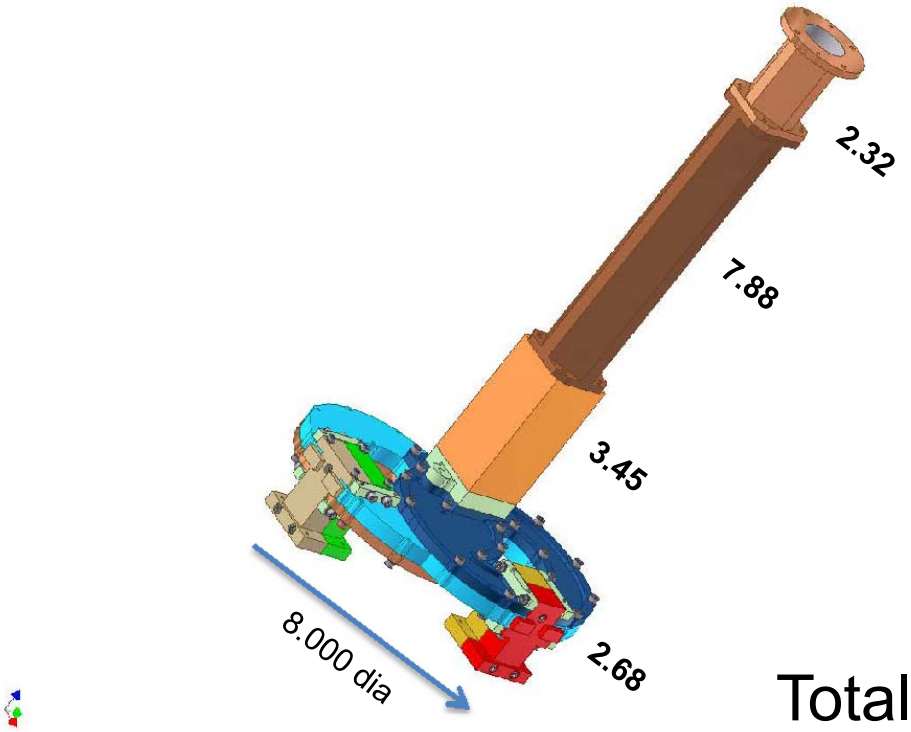
-17.4; -17.2dB

Performance of 9.25” & 8.0” OMTs (CST)





Layout of Polarizer components



Total length=16.33

Conclusions

1. Full waveguide band (8-12 GHz) OMT has been realized
2. Returns loss > 18.3 dB; Insertion loss ~0.1dB; Crosspolarization ≤ -50 dB; Port to port isolation ~ -40 dB
3. Compact: Height 2.68”; Cross-section 9.25”;Weight 4.4lbs
   Version 3:Height 2.68”, Cross-section 8.00”;Weight 2.2 lbs
4. Fabrication easy; only machined parts
5. No pins, no septum; Sturdy construction (can withstand several ‘G’ acceleration)
6. Two fold symmetry; only symmetric higher order modes if any and will cancel at output ports
7. Coupling into amplifier in waveguide transmission line

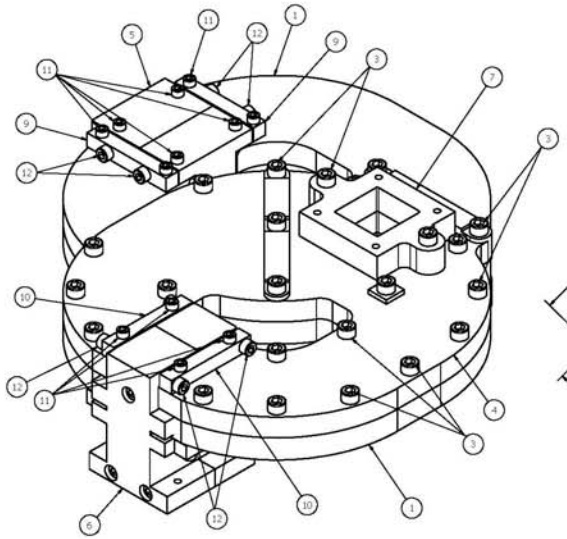
Conclusions (continued)

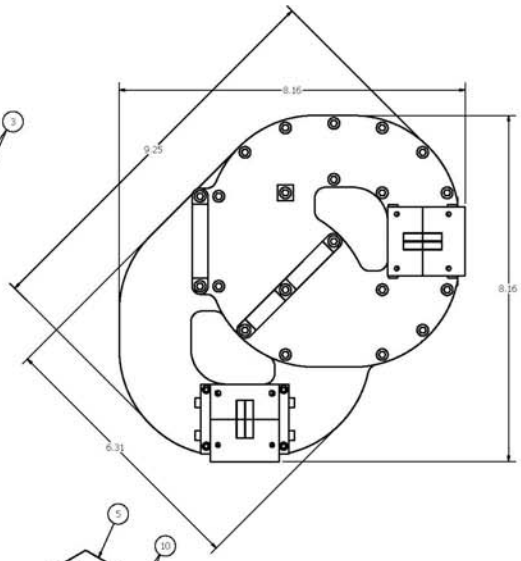
8. Waveguide isolator has ~0.2 dB lower loss compared to coax isolator
9. Turnstile OMT ~0.1 dB lower loss compared to Quadridged OMT (due to coax connector)
10. Loss due to 8 & 9 will contribute to 1.1K lower T_{rx} at 15K physical temperature; ~5% of T_{rx} at X-band (3.6% of T_{sys})
11. Poor S_{11} with coax connector may contribute to base line ripple.
12. Limiting factor with subject OMT is the turnstile junction.
13. Cost of OMT $861/piece for a lot size of 30 (J&E Precision Tool Inc., Southampton, MA)

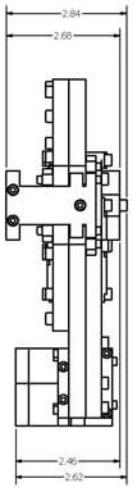

NRAO

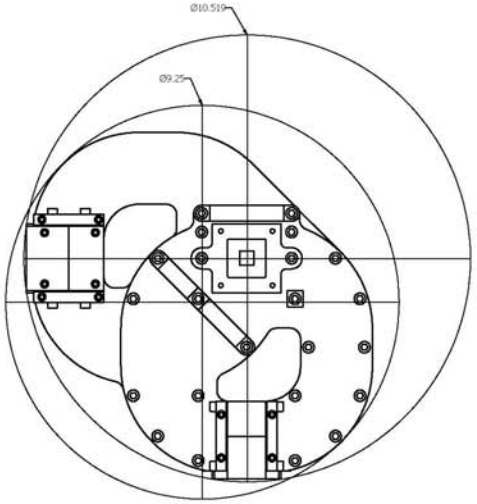

NRAO

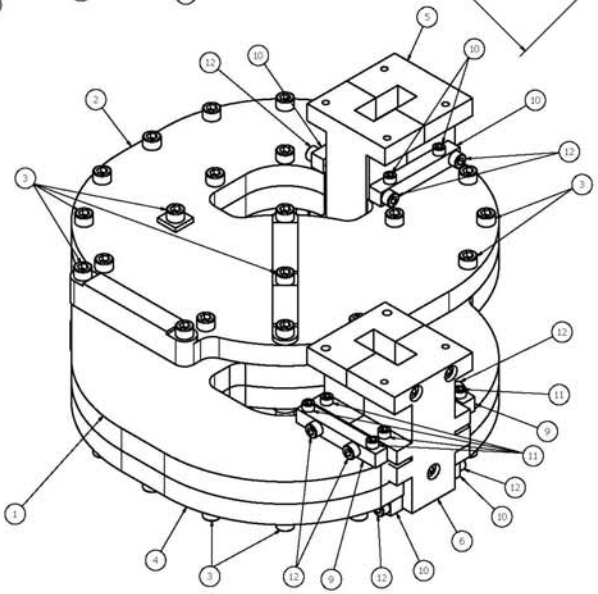

NRAO











Parts List

ITEM	QTY	PART NUMBER	DESCRIPTION
1	1	OMT MOLD-25L MIDDLE	
2	1	OMT MOLD-25L BOTTOM	
3	44	8-36 UNF - 5/8 SST	Hexagon Socket Head Cap Screw
4	1	OMT MOLD-25L TOP	
5	1	OMT PORT 15A & 15B ASSY.	
6	1	OMT PORT 16A & 16B ASSY.	
7	1	OMT ENTRY FRAME-25G	
9	4	OMT FLANGE-4	
10	4	OMT FLANGE-3	
11	24	4 - 40 UNC - 7/16 SST	Hexagon Socket Head Cap Screw
12	16	6 - 32 UNC - 1/2 SST	Hexagon Socket Head Cap Screw

NATIONAL RADIO ASTRONOMY OBSERVATORY

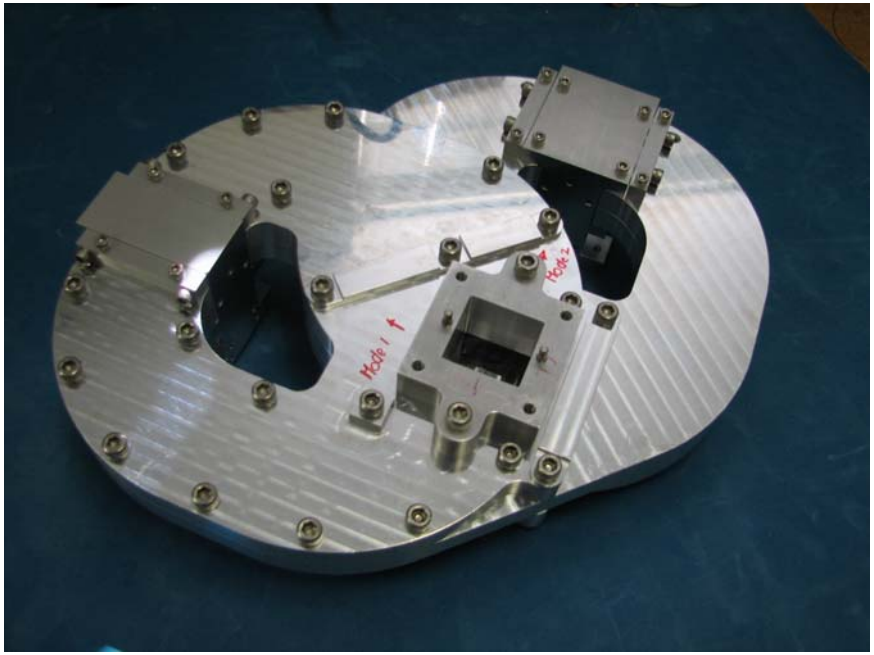
CENTER DEVELOPMENT LAB

TITLE:

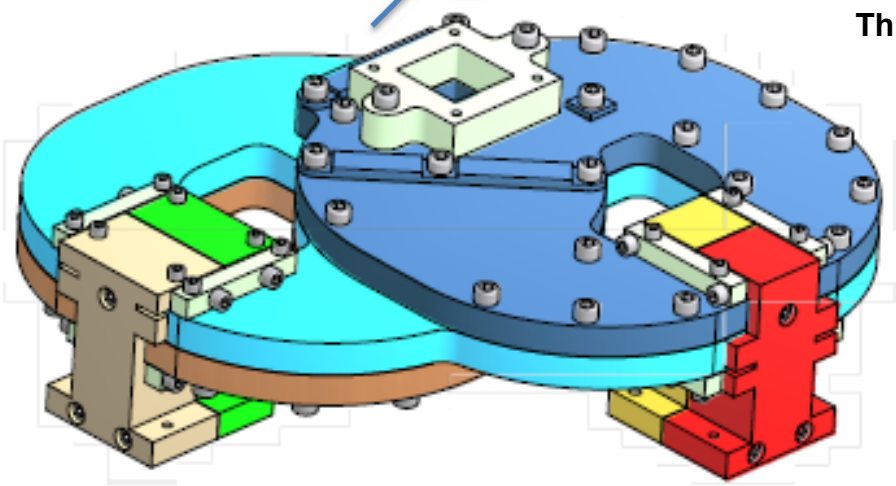
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
TOLERANCES
ANGLES ± .5°
4 PLACE DECIMALS (XXXX) ± .0005
3 PLACE DECIMALS (XXX) ± .001
2 PLACE DECIMALS (XX) ± .010
MATERIAL: N/A
FINISH: N/A

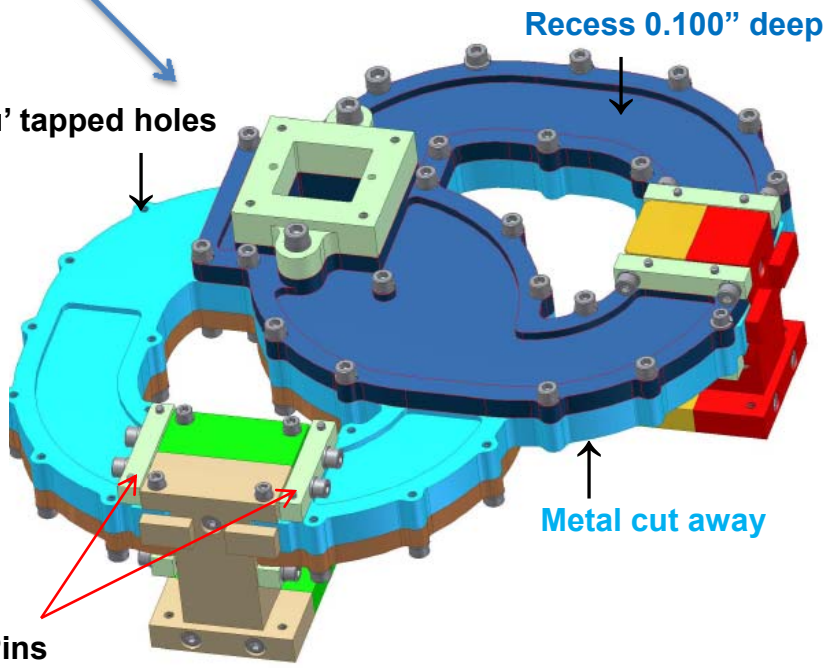
	NAME	DATE	SIGNATURE	DATE
DESIGN	mscilatka	12/11/2008	RECOMMENDED BY:	
DRAWN	MJS	12/12/08	ENGINEER	
CHECKED			APPROVED	

SCALE: NTS | SIZE: D | SHEET: 1 OF 1 | DWG NO: OMT 25L ASSY. | REV:


Mode 1
Mode 2

Jillian Michaels Weight Loss Program





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