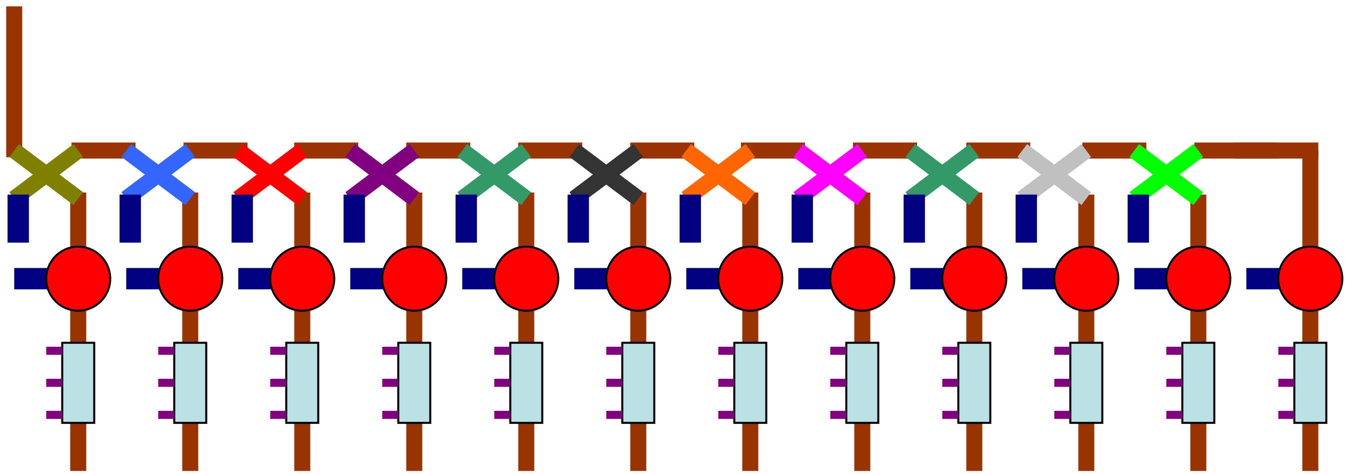
Power distribution system for ILC.

Can we avoid expansive circulators ?

S.Kazakov

05-18-06

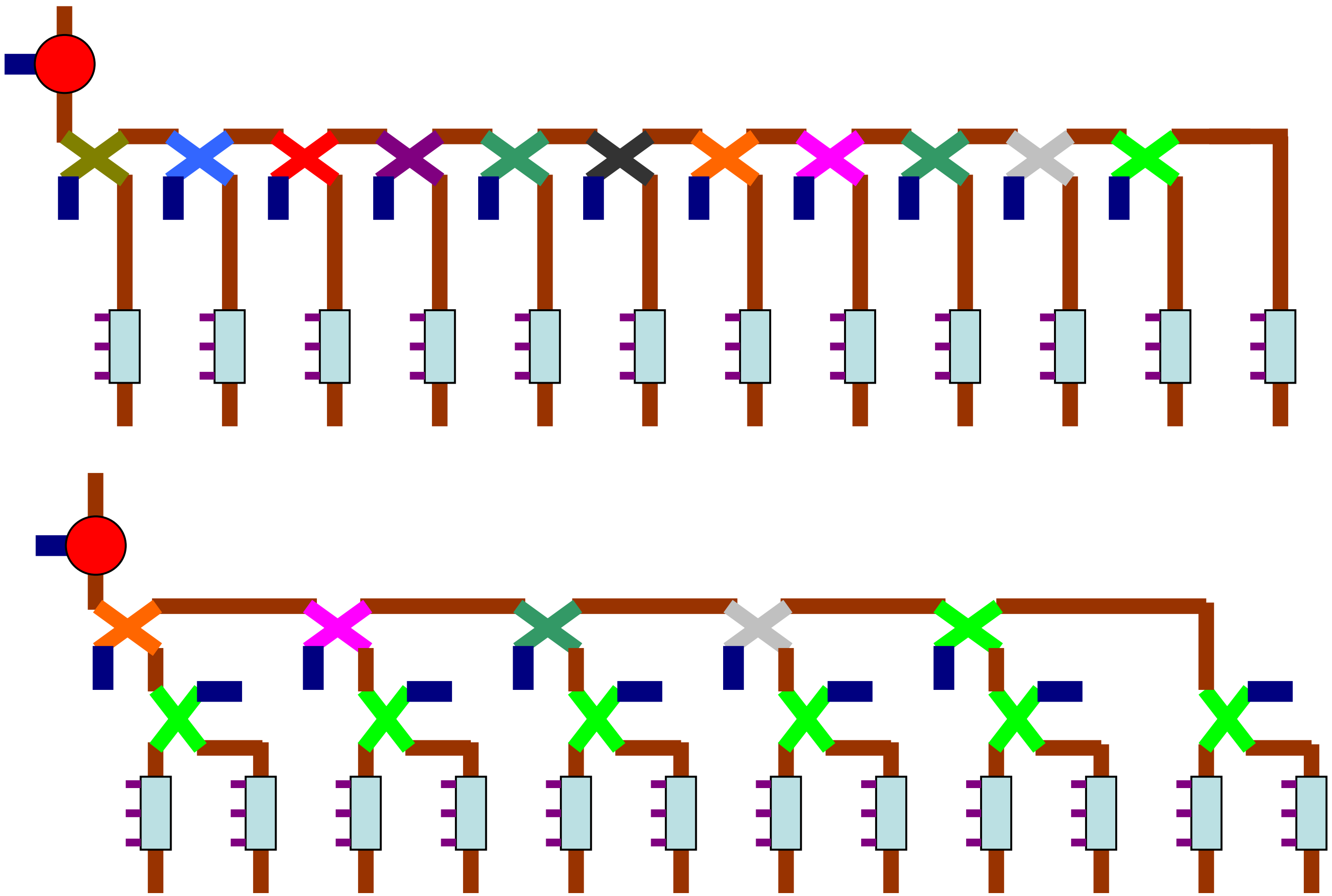
Baseline design



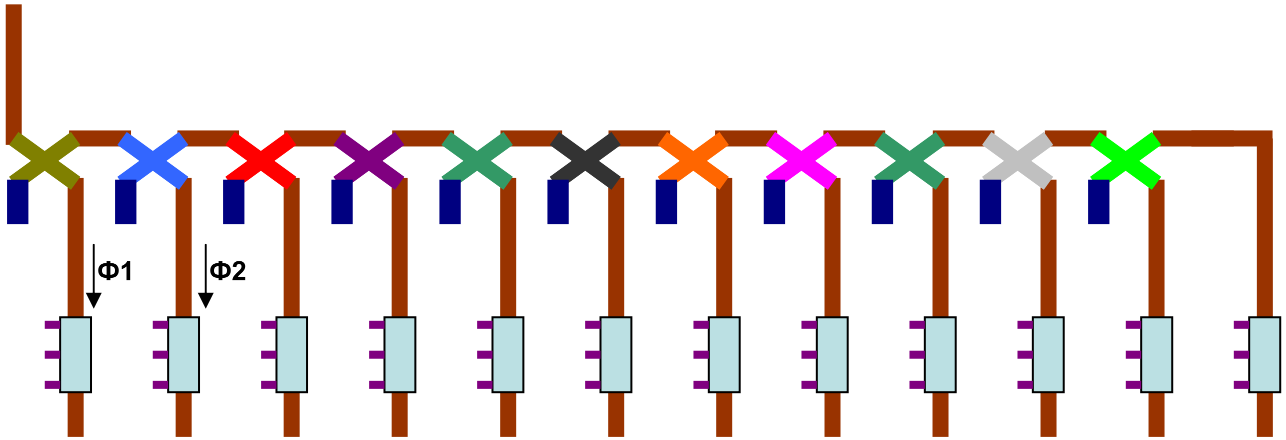
Alternative schemes:

One big circulator for klystron protection instead of several small ones.

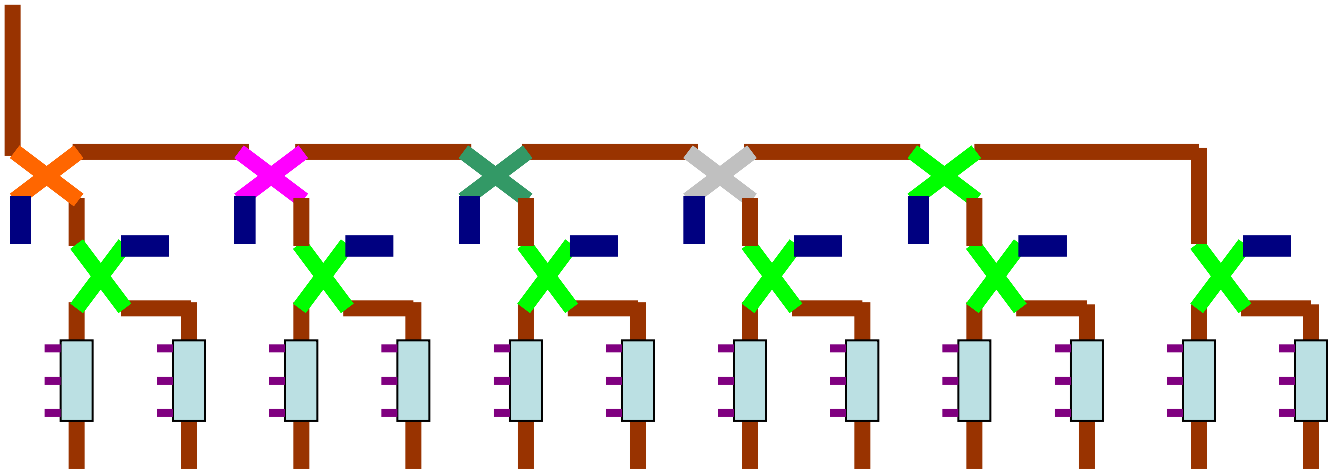
Price of big circulator ~ 4 x small circulator (?)



No circulators:



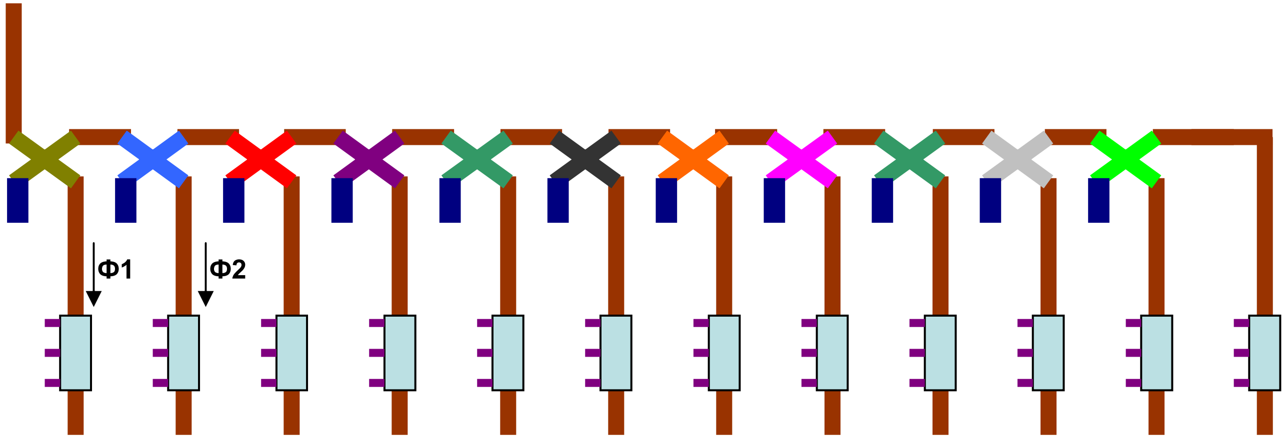
dΦ = Φ1-Φ2 = mπ/n – no reflection to the klystron (Tantawi)



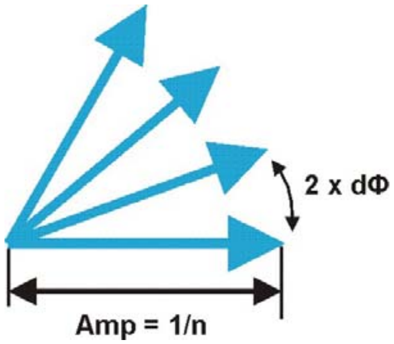
(Nantista)

Both schemes (Tantawi, Nantista) work well if all elements ideal:
no crosstalk between structure;
no reflection to klystron if all reflections from structures are equal;
breakdown in one structure causes $(1/n)^2$ power reflection to the klystron;

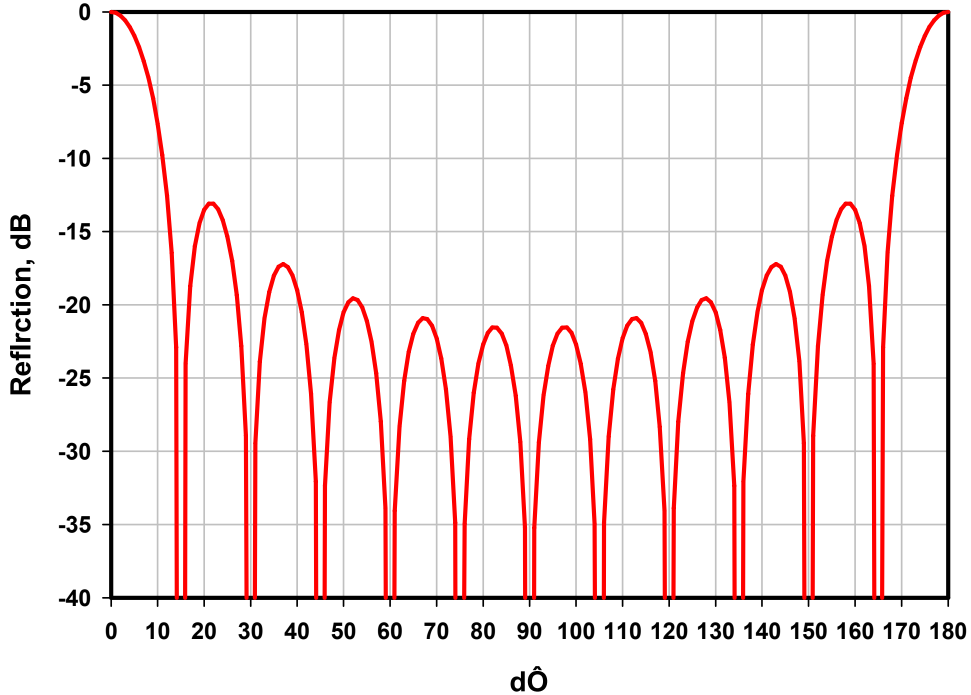
Question: How ideal elements (direction couplers, loads) must be?



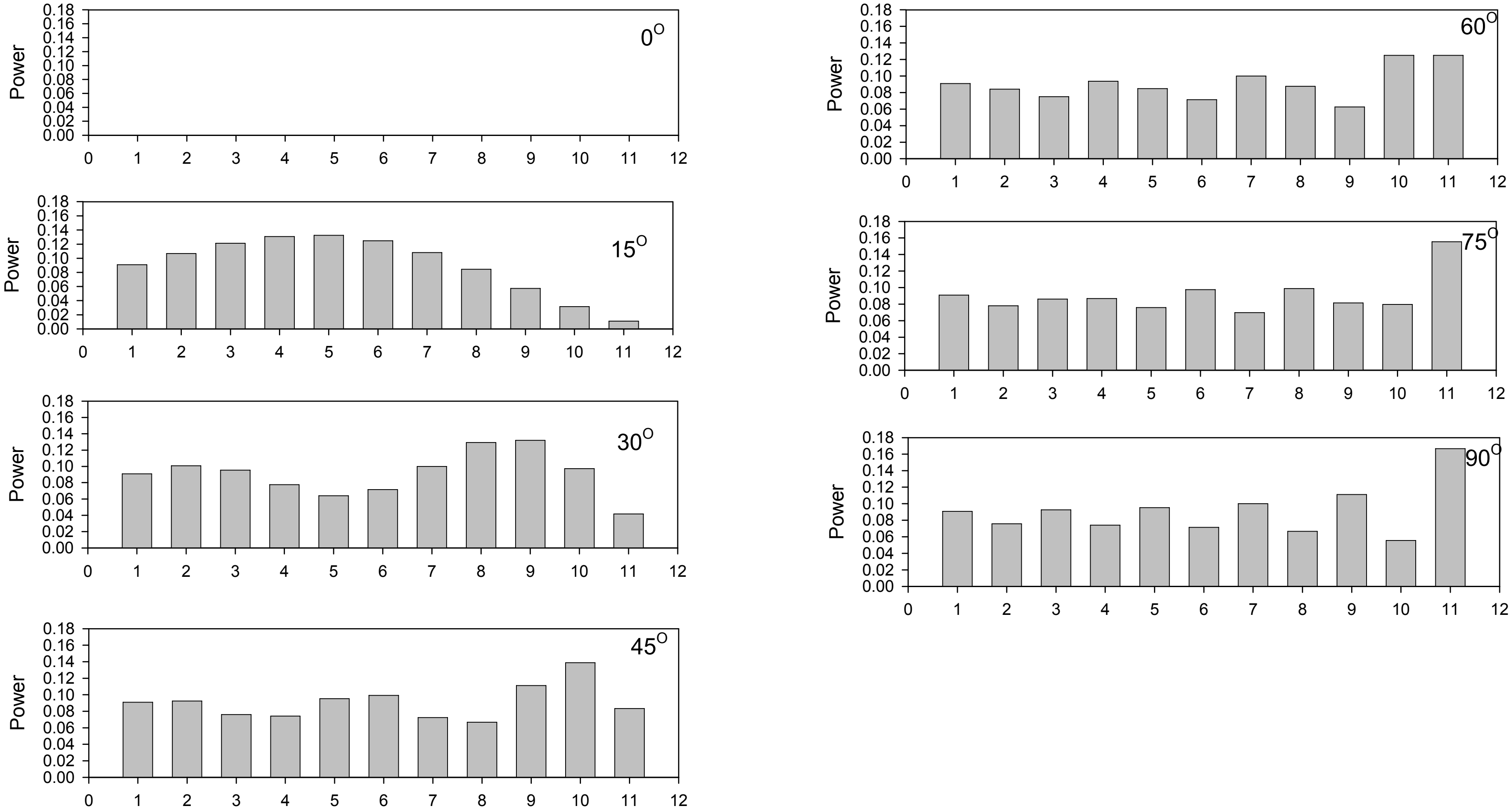
dΦ = Φ1-Φ2



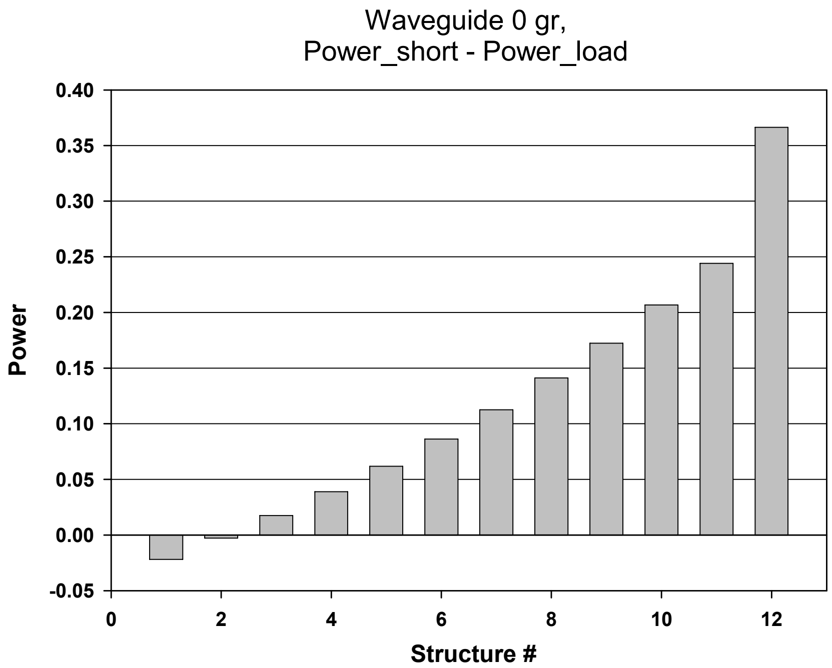
Reflection from all structures, dB
n =12

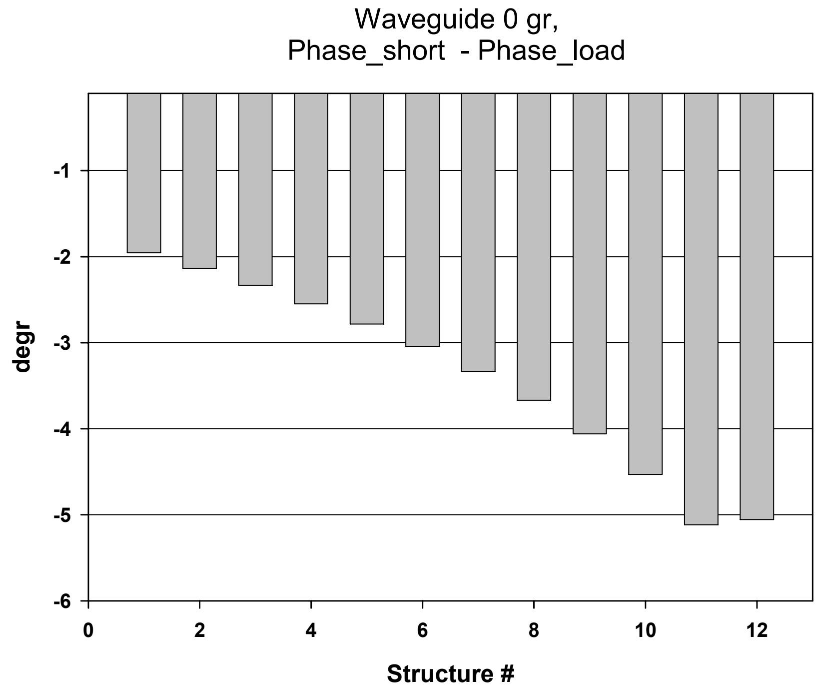


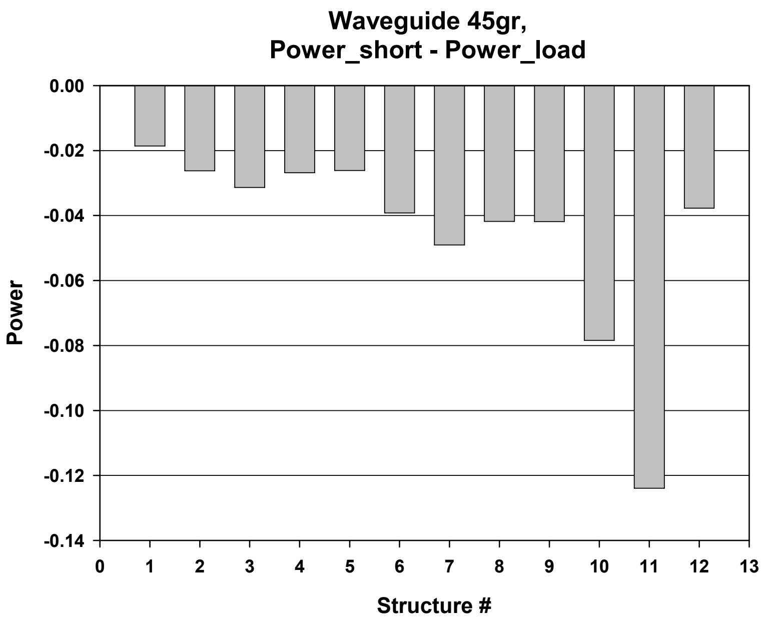
Power distribution in loads

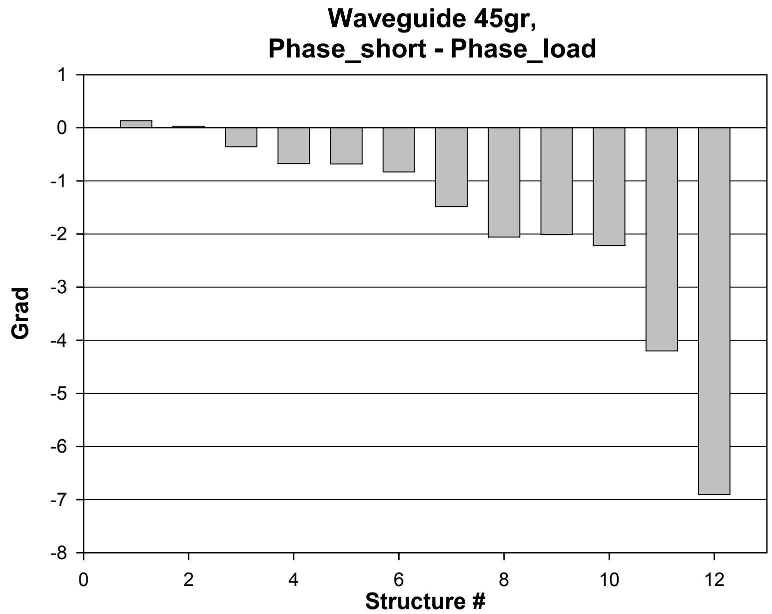


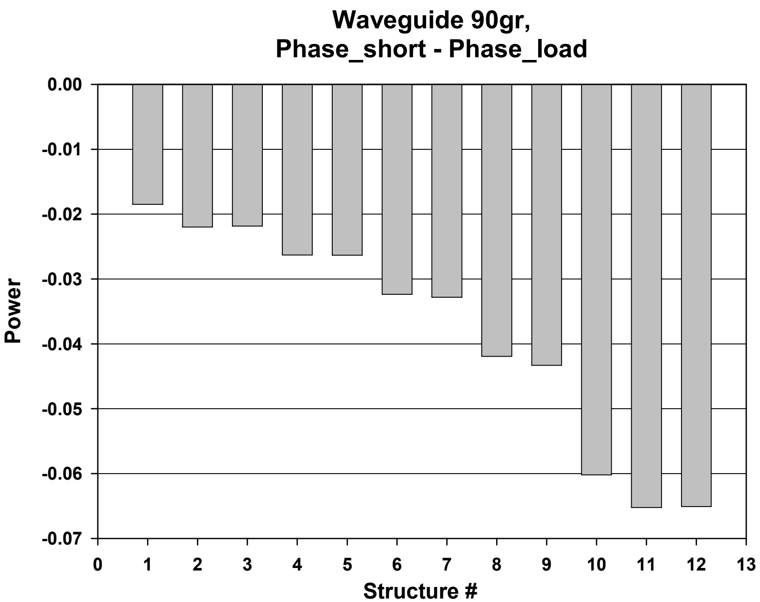
Non-ideal elements, -30db directivity and reflection

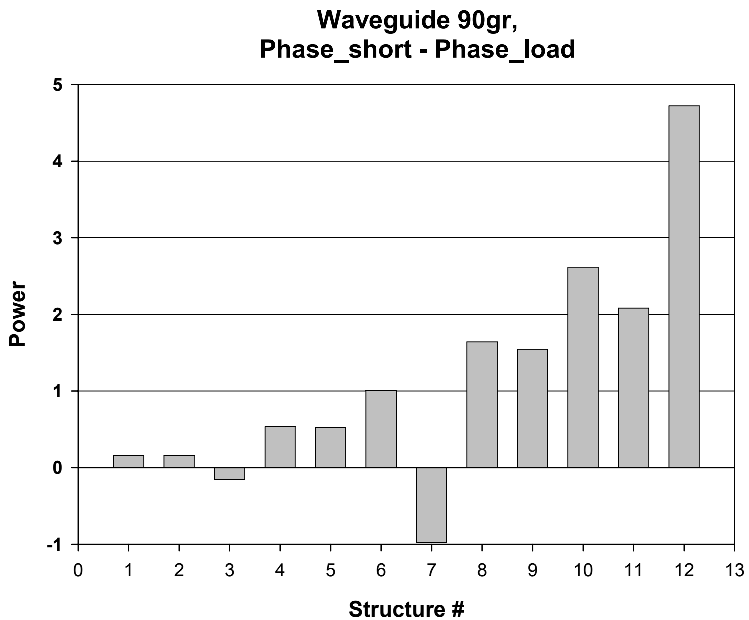




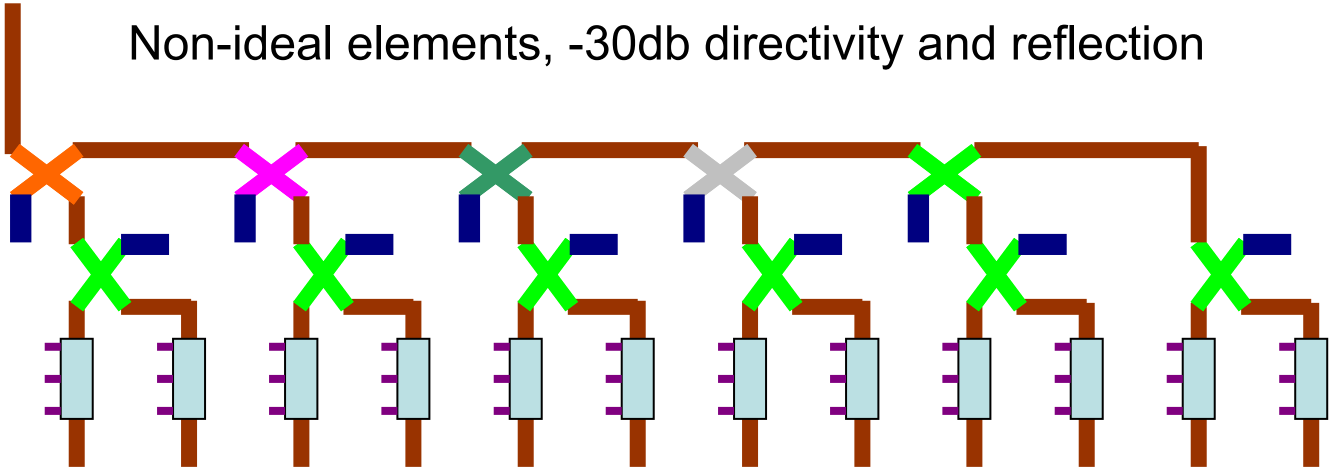

Waveguide 45gr,
Power_short - Power_load
Power
0.00
-0.02
-0.04
-0.06
-0.08
-0.10
-0.12
-0.14
0 1 2 3 4 5 6 7 8 9 10 11 12 13
Structure #

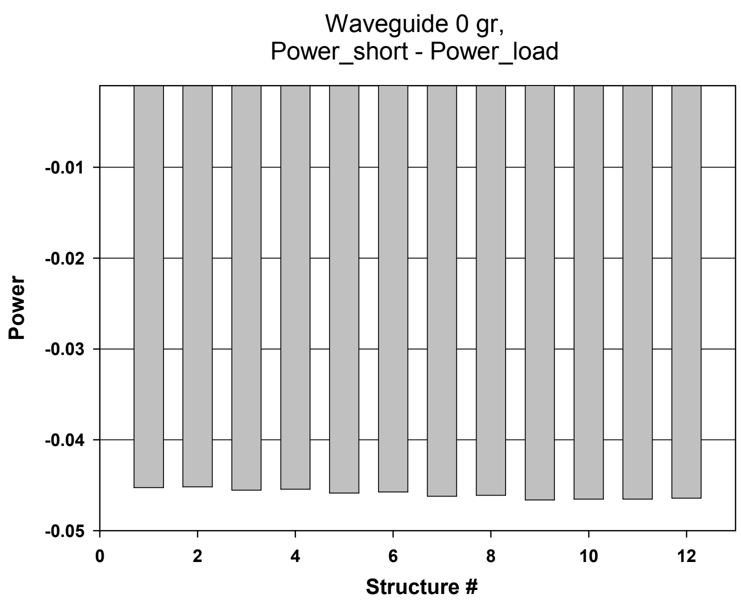

Waveguide 45gr,
Phase_short - Phase_load
Grad
1
0
-1
-2
-3
-4
-5
-6
-7
-8
0 2 4 6 8 10 12
Structure #

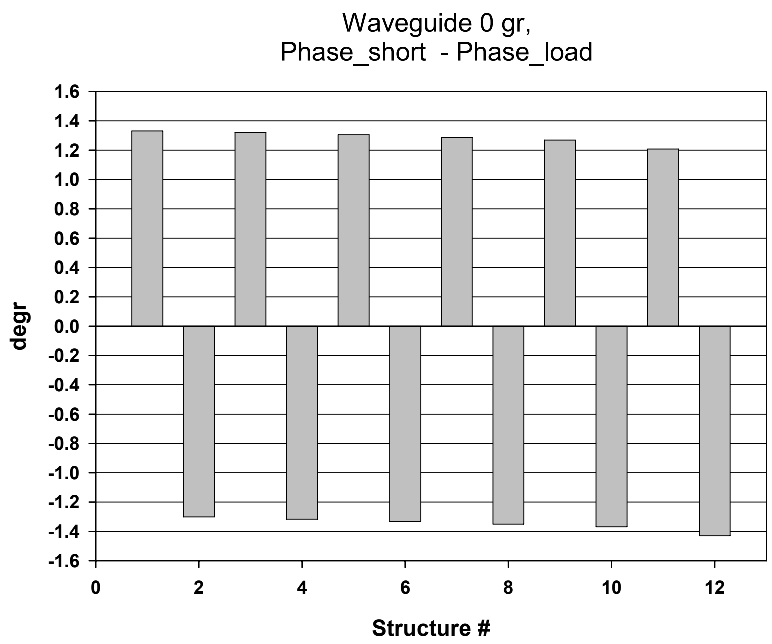

Waveguide 90gr,
Phase_short - Phase_load
Power
0.00
-0.01
-0.02
-0.03
-0.04
-0.05
-0.06
-0.07
0 1 2 3 4 5 6 7 8 9 10 11 12 13
Structure #

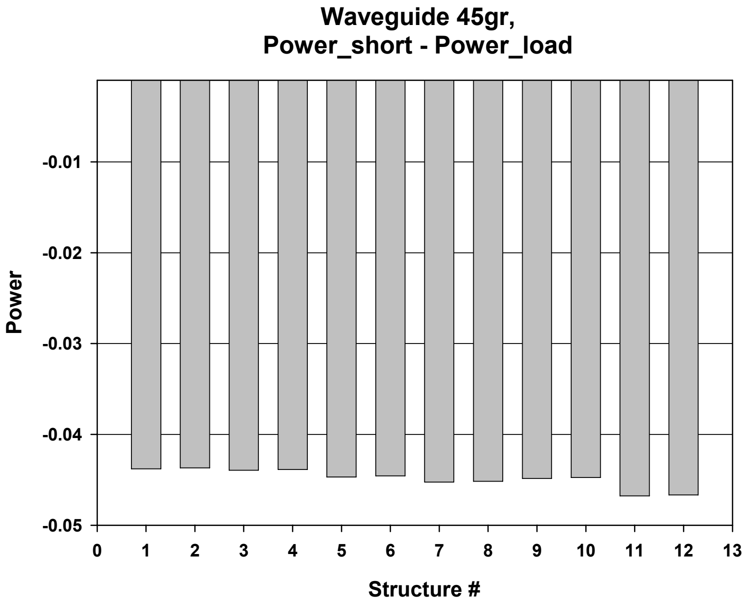

Waveguide 90gr,
Phase_short - Phase_load
Power
5
4
3
2
1
0
-1
0 1 2 3 4 5 6 7 8 9 10 11 12 13
Structure #

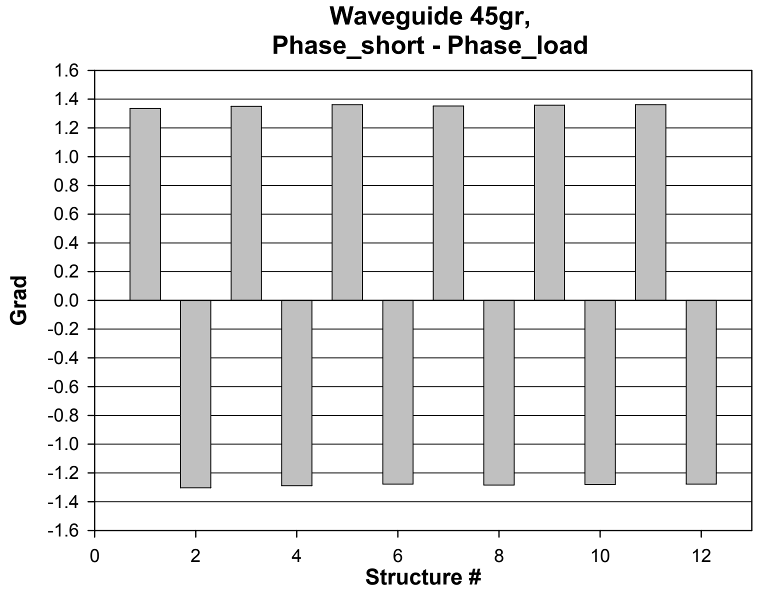
Non-ideal elements, -30db directivity and reflection

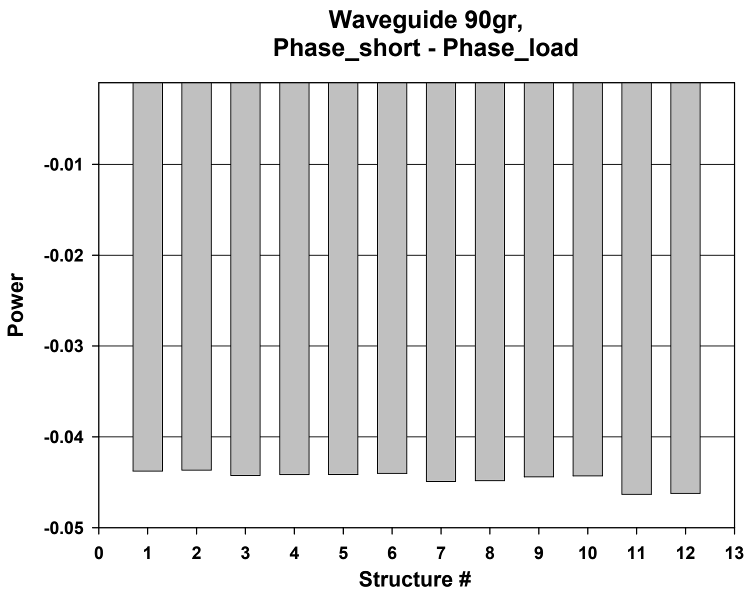


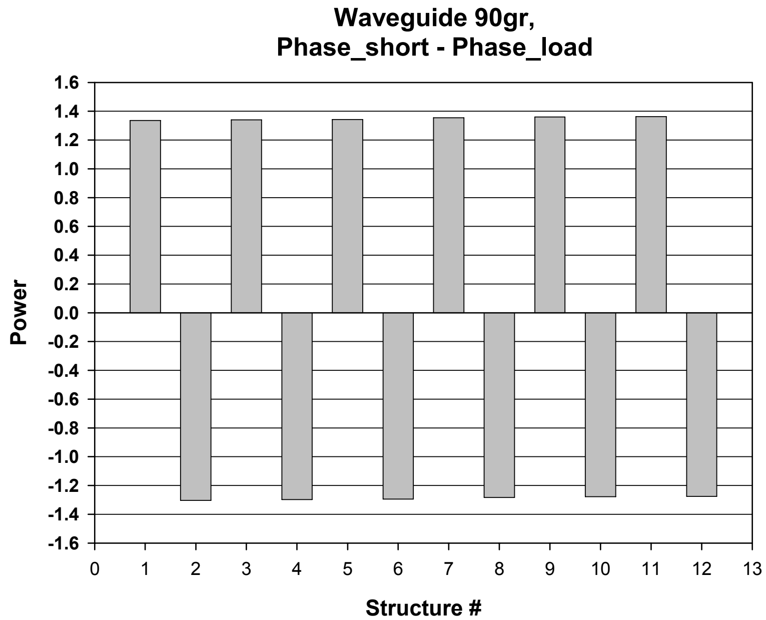





Waveguide 45gr,
Power_short - Power_load
Power
-0.01
-0.02
-0.03
-0.04
-0.05
0 1 2 3 4 5 6 7 8 9 10 11 12 13
Structure #

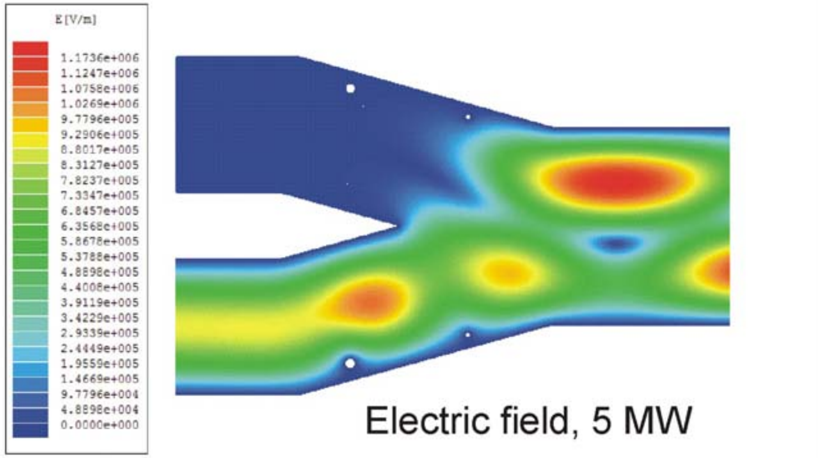

Waveguide 45gr,
Phase_short - Phase_load
Grad
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
-0.8
-1.0
-1.2
-1.4
-1.6
0 2 4 6 8 10 12
Structure #


Waveguide 90gr,
Phase_short - Phase_load
Power
-0.01
-0.02
-0.03
-0.04
-0.05
0 1 2 3 4 5 6 7 8 9 10 11 12 13
Structure #

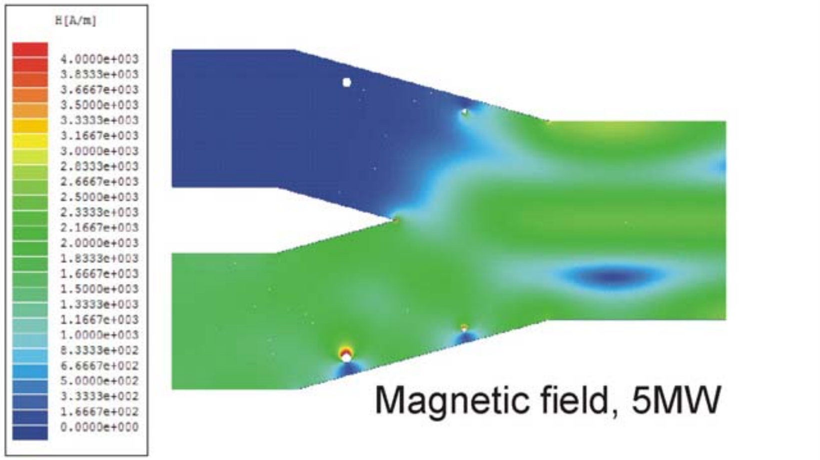

Waveguide 90gr,
Phase_short - Phase_load
Power
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
-0.8
-1.0
-1.2
-1.4
-1.6
0 1 2 3 4 5 6 7 8 9 10 11 12 13
Structure #

WR650 Elements

Probably the -30db perfection is enough (?)
Design of high perfection direction coupler. Semi-hybrid approach:

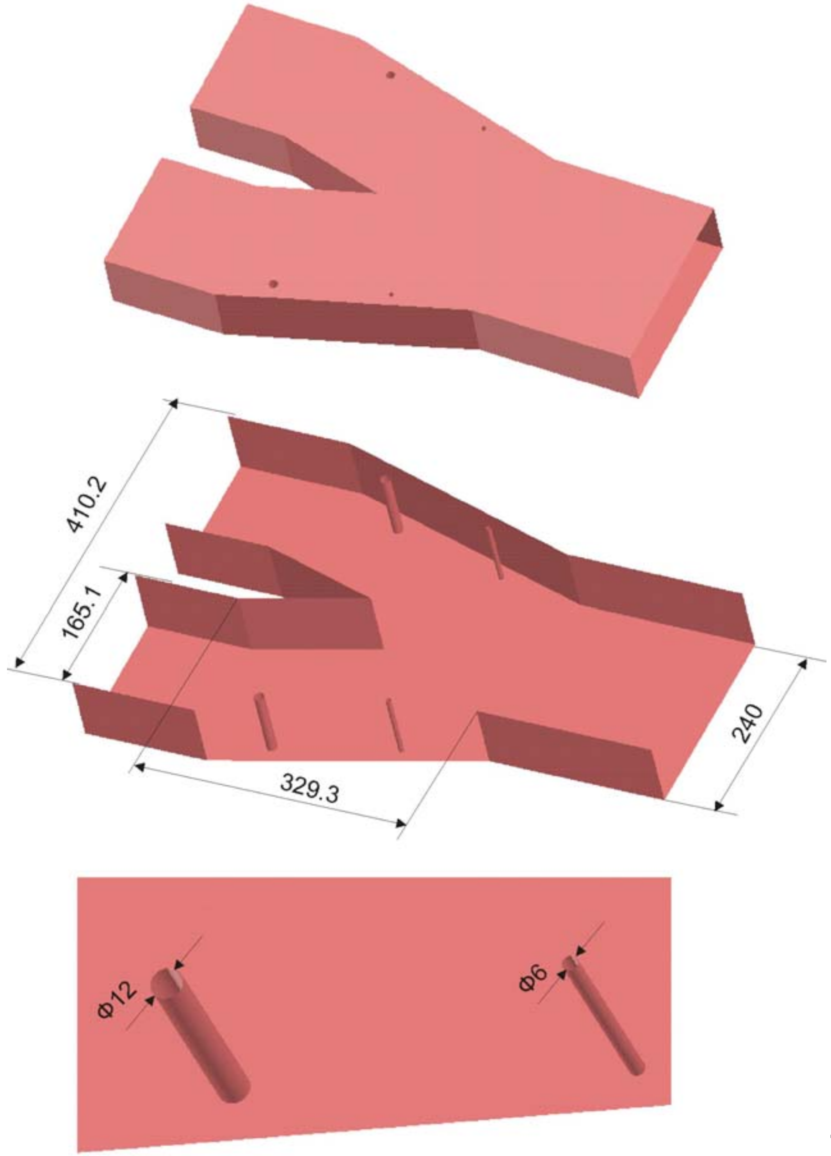


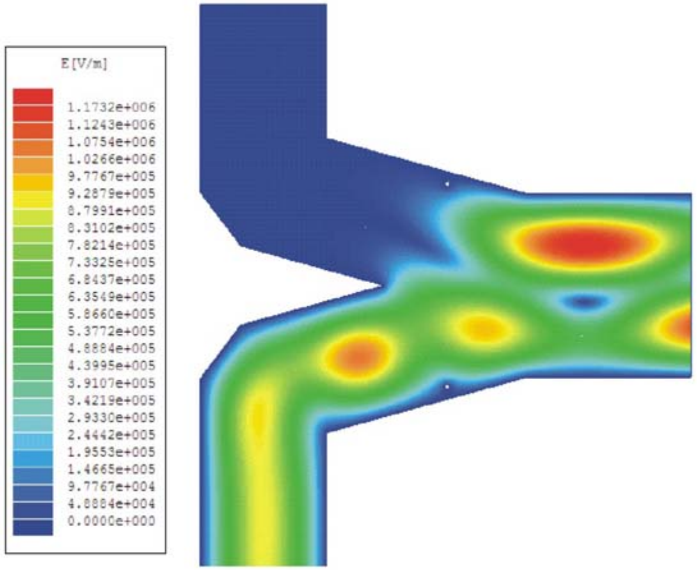
Electric field, 5 MW

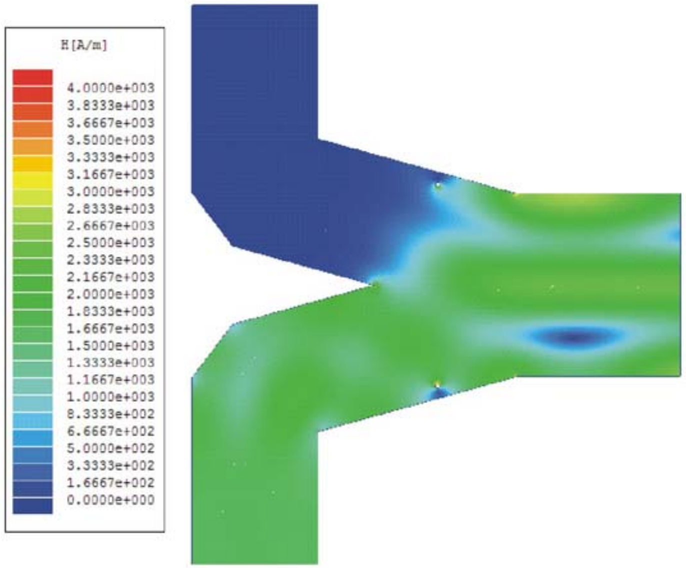


Magnetic field, 5MW

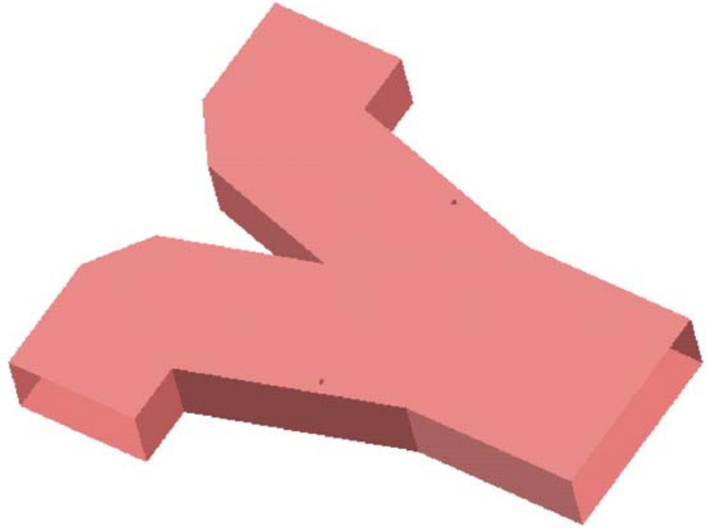
	port1:m1	port2:m1	port3:m1	port3:m2
port1:m1	(0.00361, 129.668)	(0.00363, 24.603)	(0.70710, 41.523)	(0.70709, 170.382)
port2:m1	(0.00363, 24.603)	(0.00361, 129.747)	(0.70710, 41.522)	(0.70710, -9.618)
port3:m1	(0.70710, 41.523)	(0.70710, 41.522)	(0.00440,-173.865)	(2.74616e-006, -32.361)
port3:m2	(0.70709, 170.382)	(0.70710, -9.618)	(2.74617e-006, -32.361)	(0.00575, -6.536)

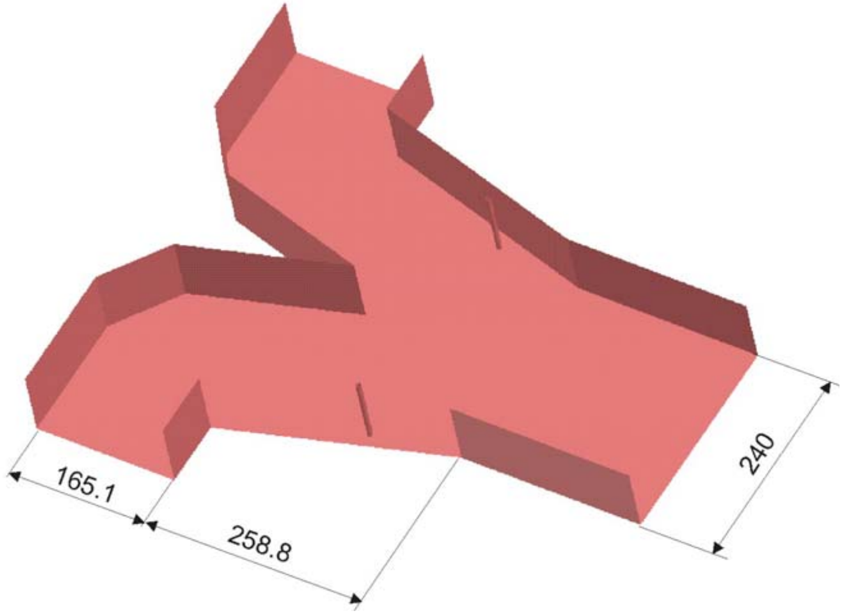


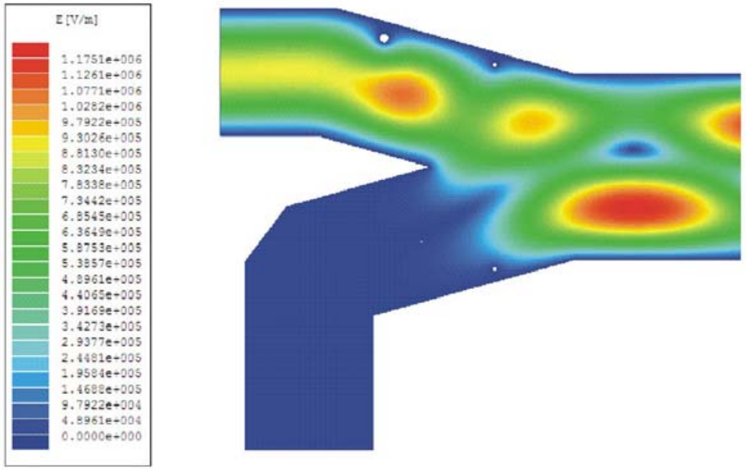




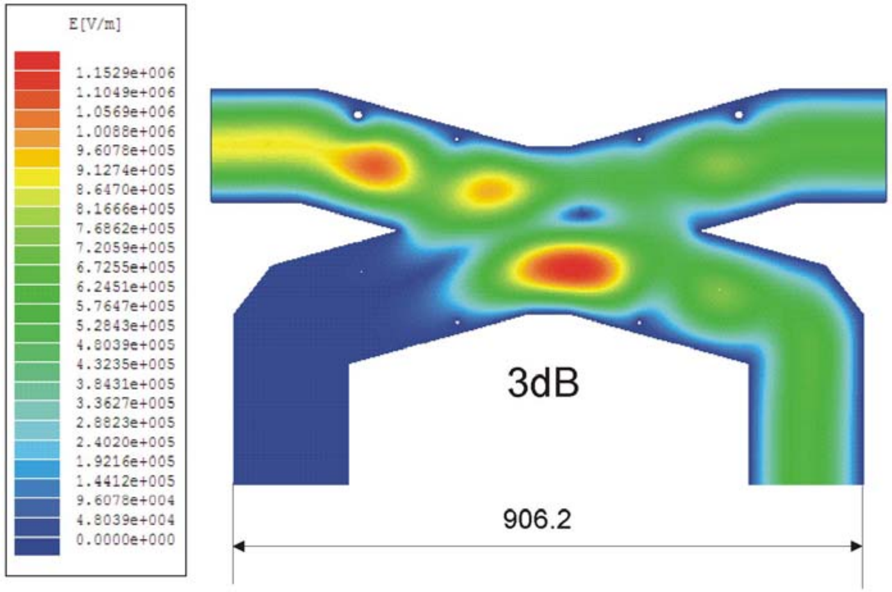
	port1:m1	port2:m1	port3:m1	port3:m2
port1:m1	(0.00453,-112.971)	(0.00131, -75.845)	(0.70710, 92.981)	(0.70710, 42.129)
port2:m1	(0.00131, -75.845)	(0.00453,-112.946)	(0.70710, -87.019)	(0.70710, 42.129)
port3:m1	(0.70710, 92.981)	(0.70710, -87.019)	(0.00357, 131.704)	(2.19355e-006,-138.919)
port3:m2	(0.70710, 42.129)	(0.70710, 42.129)	(2.19355e-006,-138.919)	(0.00563, 9.145)



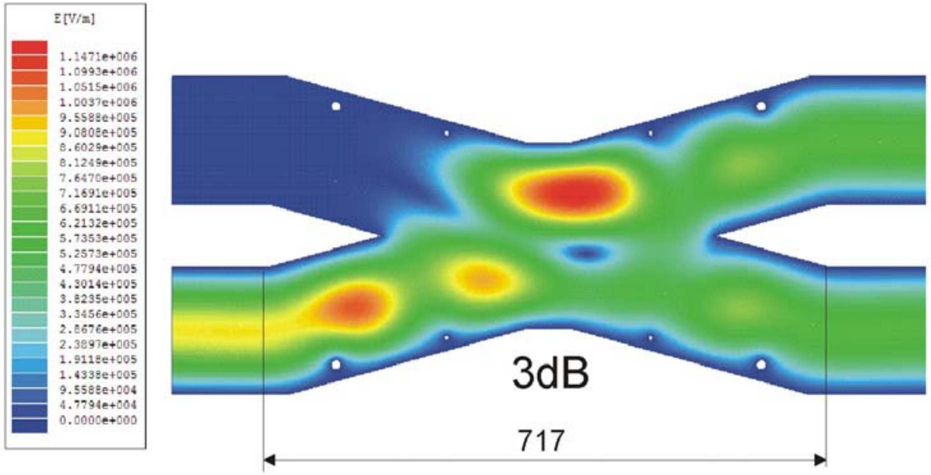




Reflection -48.9dB
Isolation   -49.1dB
Directivity 46.1dB

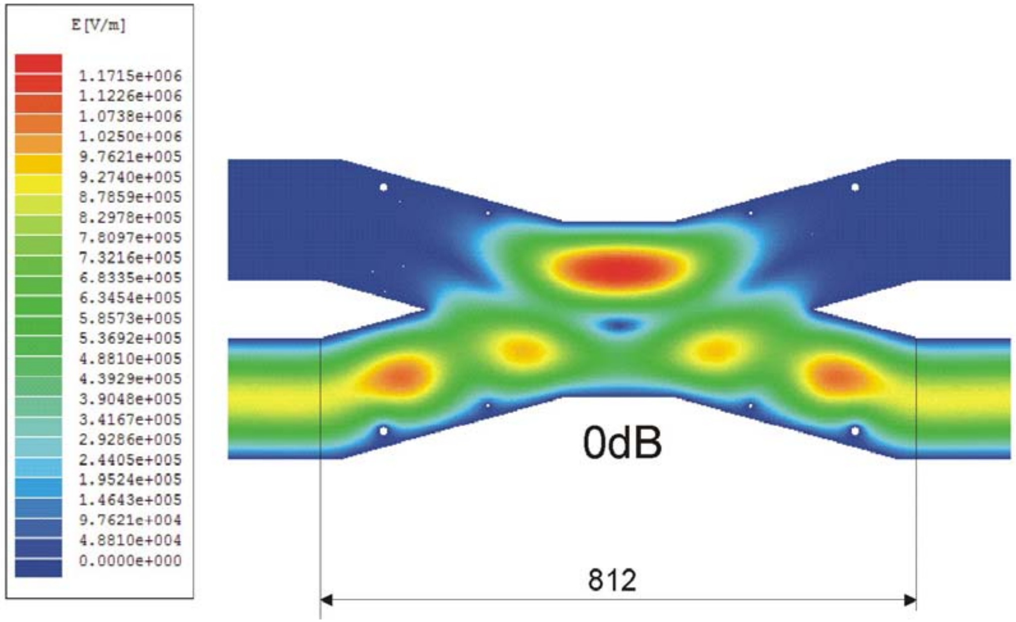


	port1:m1	port2:m1	port3:m1	port4:m1
port1:m1	(0.00357, -88.193)	(0.00350, -8.750)	(0.70734, 109.704)	(0.70686, -31.914)
port2:m1	(0.00350, -8.750)	(0.00362, 170.854)	(0.70685, -31.909)	(0.70734, 6.471)
port3:m1	(0.70734, 109.704)	(0.70685, -31.909)	(0.00357, -94.117)	(0.00360, -15.186)
port4:m1	(0.70686, -31.914)	(0.70734, 6.471)	(0.00360, -15.186)	(0.00344, 163.942)



Reflection -50.7dB
Isolation -50.7dB
Directivity 47.7dB

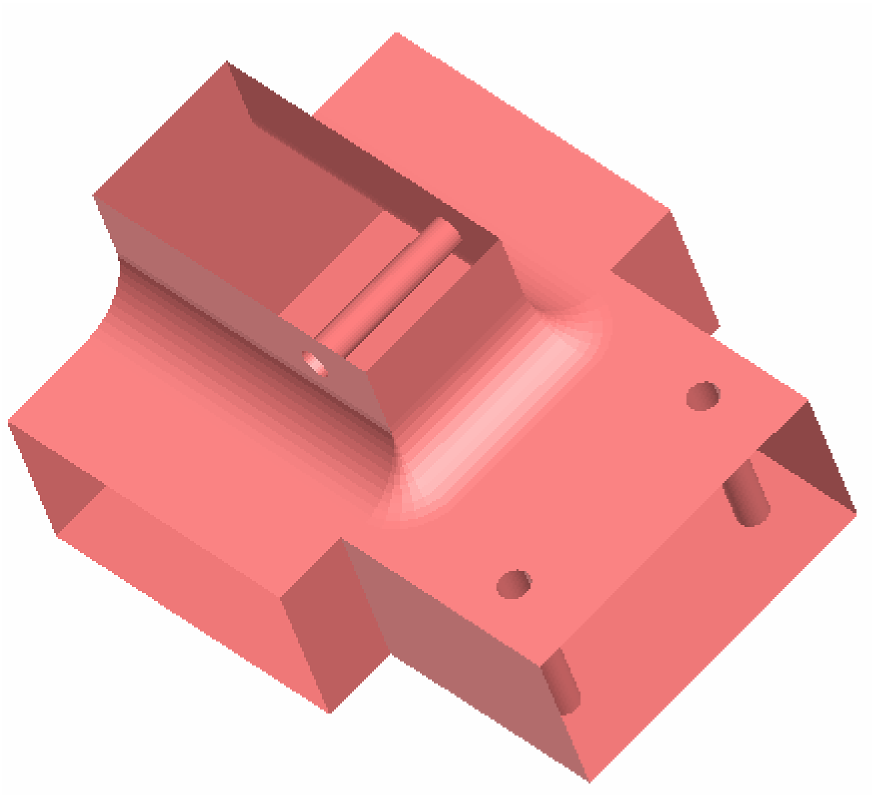
	port1:m1	port2:m1	port3:m1
port1:m1	(0.00290,-169.073)	(0.00290, -87.988)	(0.70592, 6.437)
port2:m1	(0.00290, -87.988)	(0.00290,-169.177)	(0.70828, -83.563)
port3:m1	(0.70592, 6.437)	(0.70828, -83.563)	(0.00291,-169.120)
port4:m1	(0.70828, -83.563)	(0.70592, 6.437)	(0.00289, -88.030)



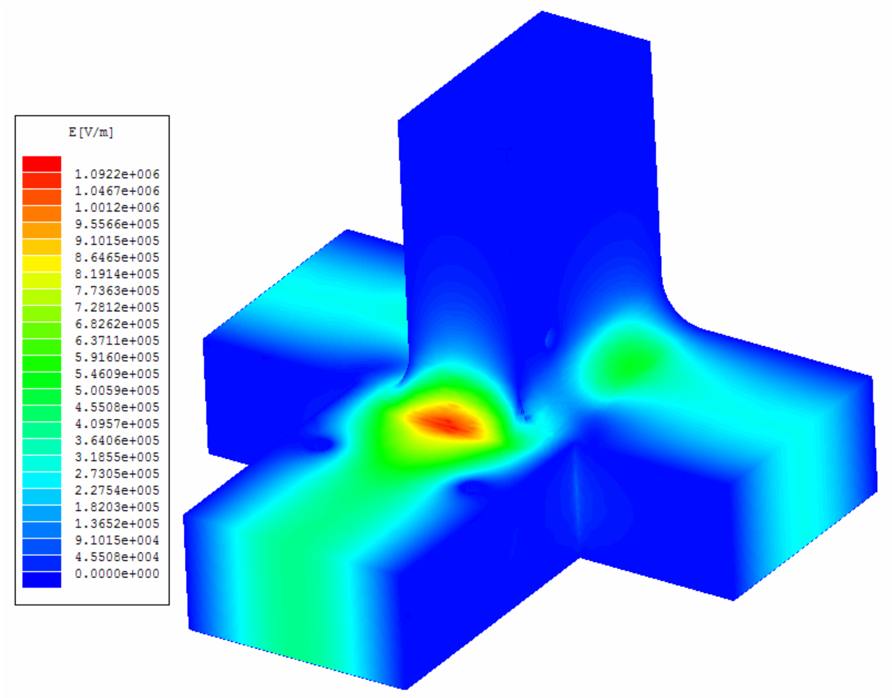
Reflection -49.4dB
Isolation -43.1dB
Directivity 43.7dB

	port1:m1	port2:m1	port3:m1	port4:m1
port1:m1	(0.00344,-171.320)	(0.00702, 10.436)	(0.99994, 100.543)	(0.00739, 10.387)
port2:m1	(0.00702, 10.436)	(0.00348,-170.916)	(0.00739,-169.677)	(0.99994, -79.457)
port3:m1	(0.99994, 100.543)	(0.00739,-169.677)	(0.00344,-169.324)	(0.00702,-169.767)
port4:m1	(0.00739, 10.387)	(0.99994, -79.457)	(0.00702,-169.767)	(0.00348,-169.707)

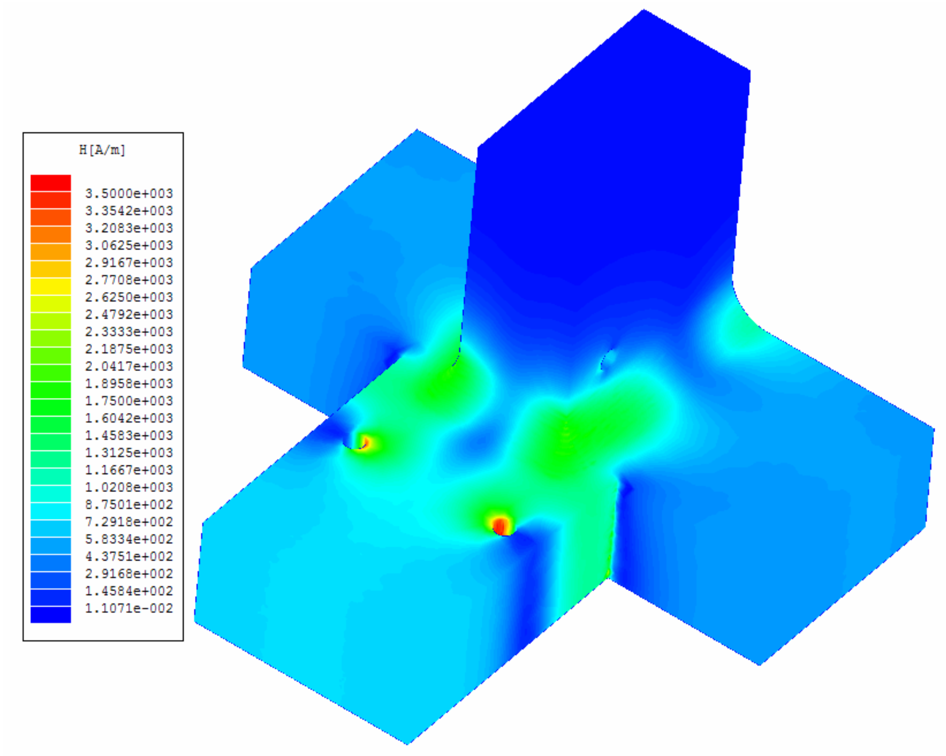
Checking Magic-T – compact device with perfect symmetry



Power = 1MW

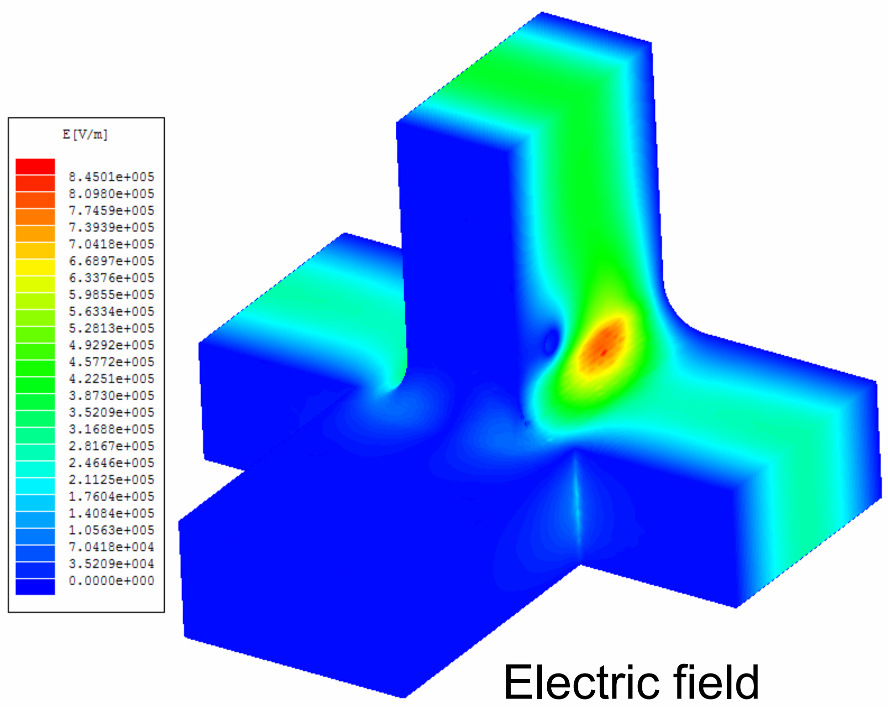


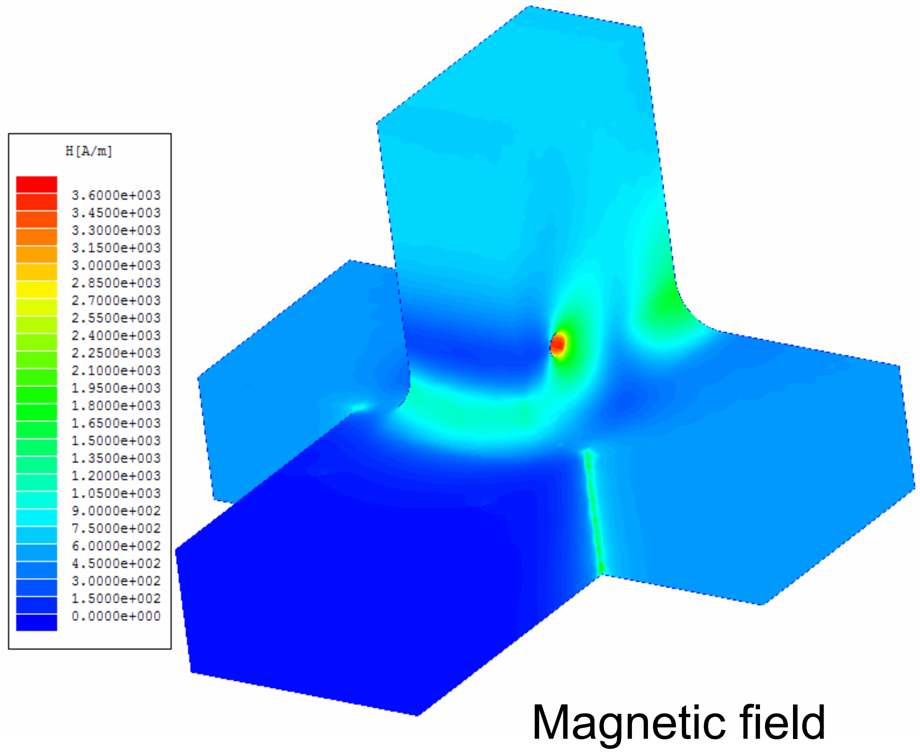
Electric field



Magnetic field

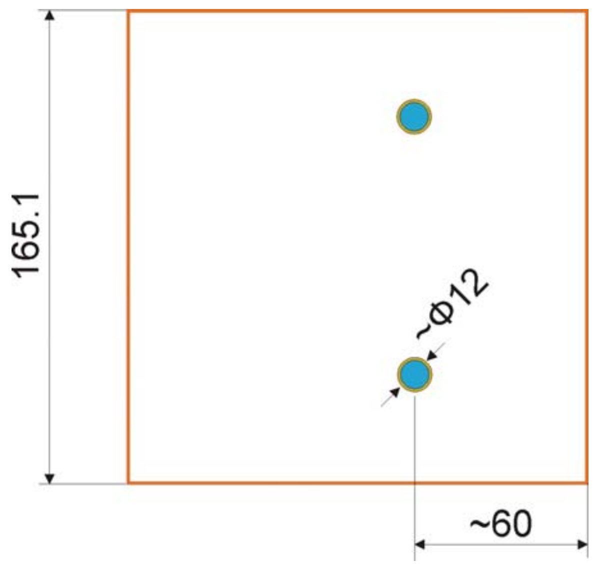
Power = 1MW

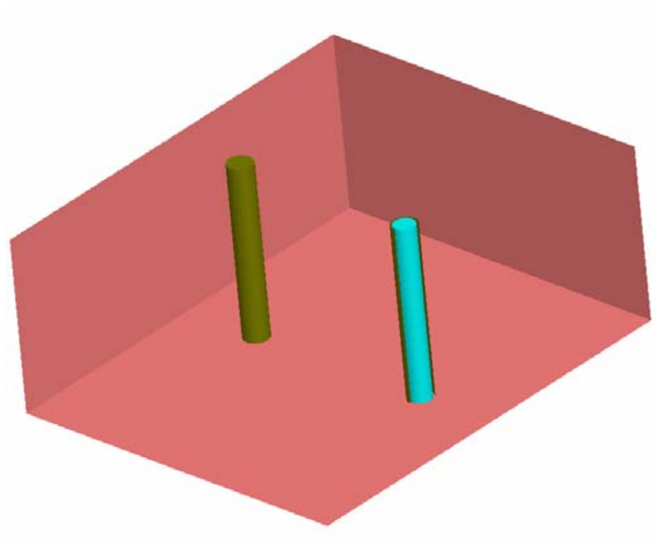


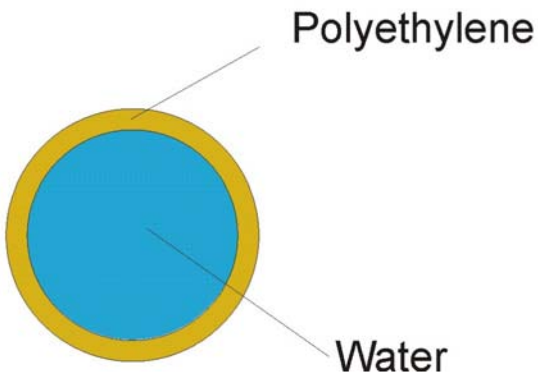


Maximum electric field at the surface of Magic-T depends on phases of reflected waves coming from arms. Minimum maximum for 1 MW is 15.5kV/cm

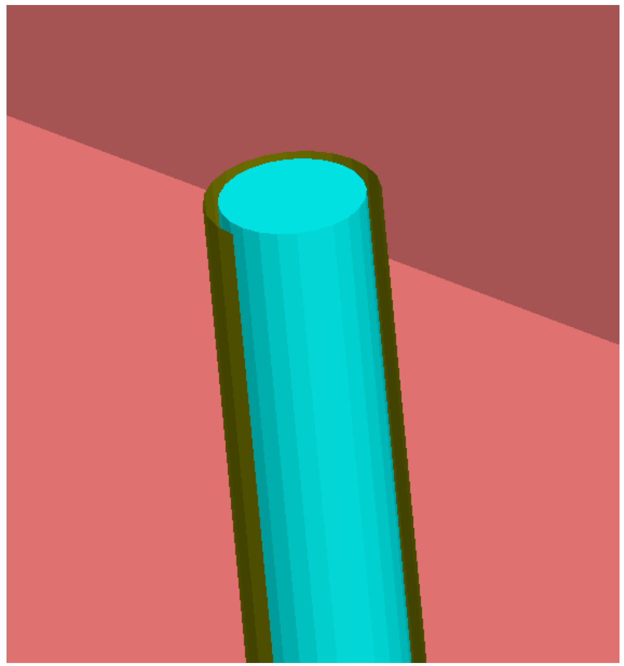
Cheap, simple L-band load

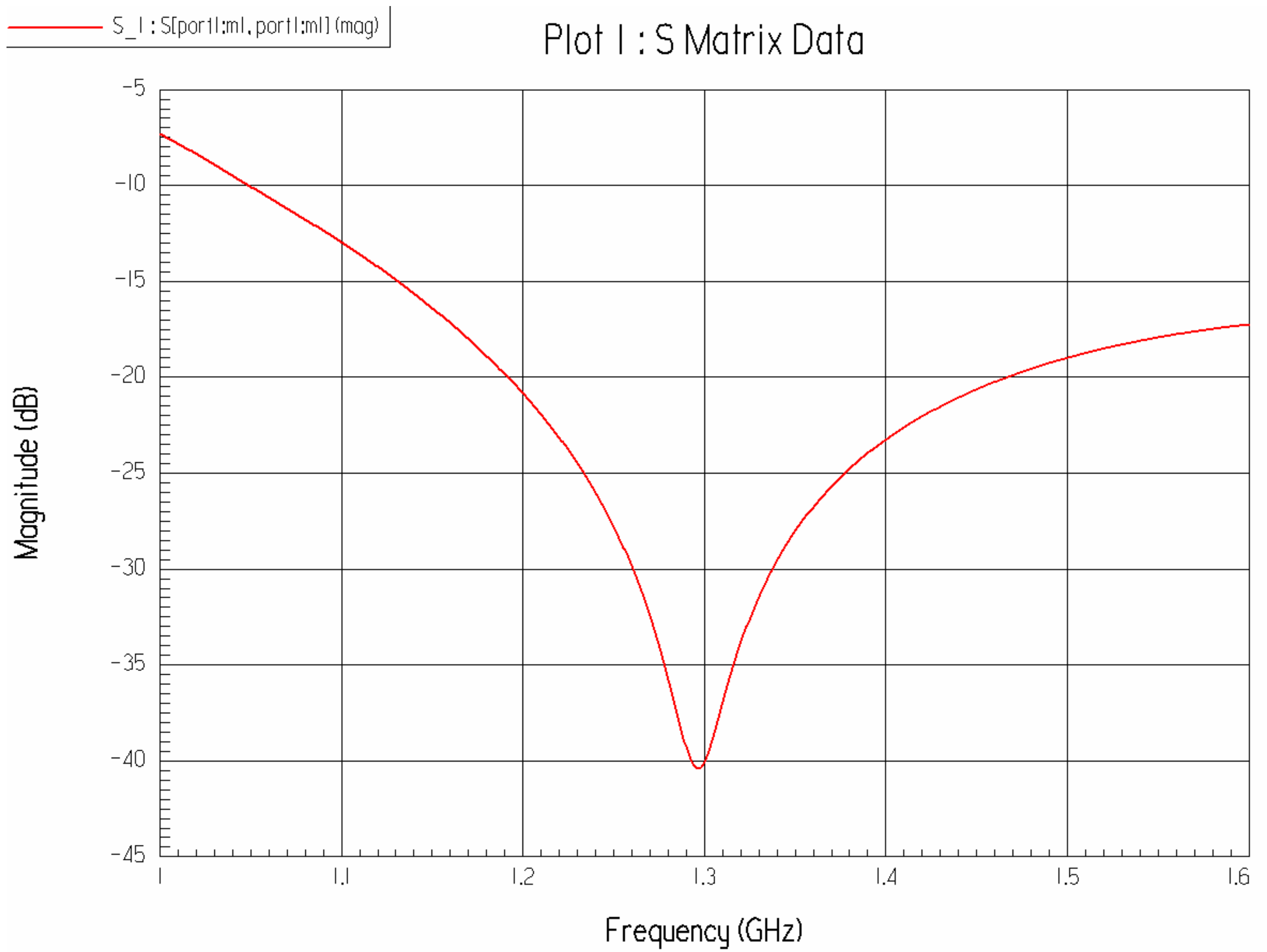






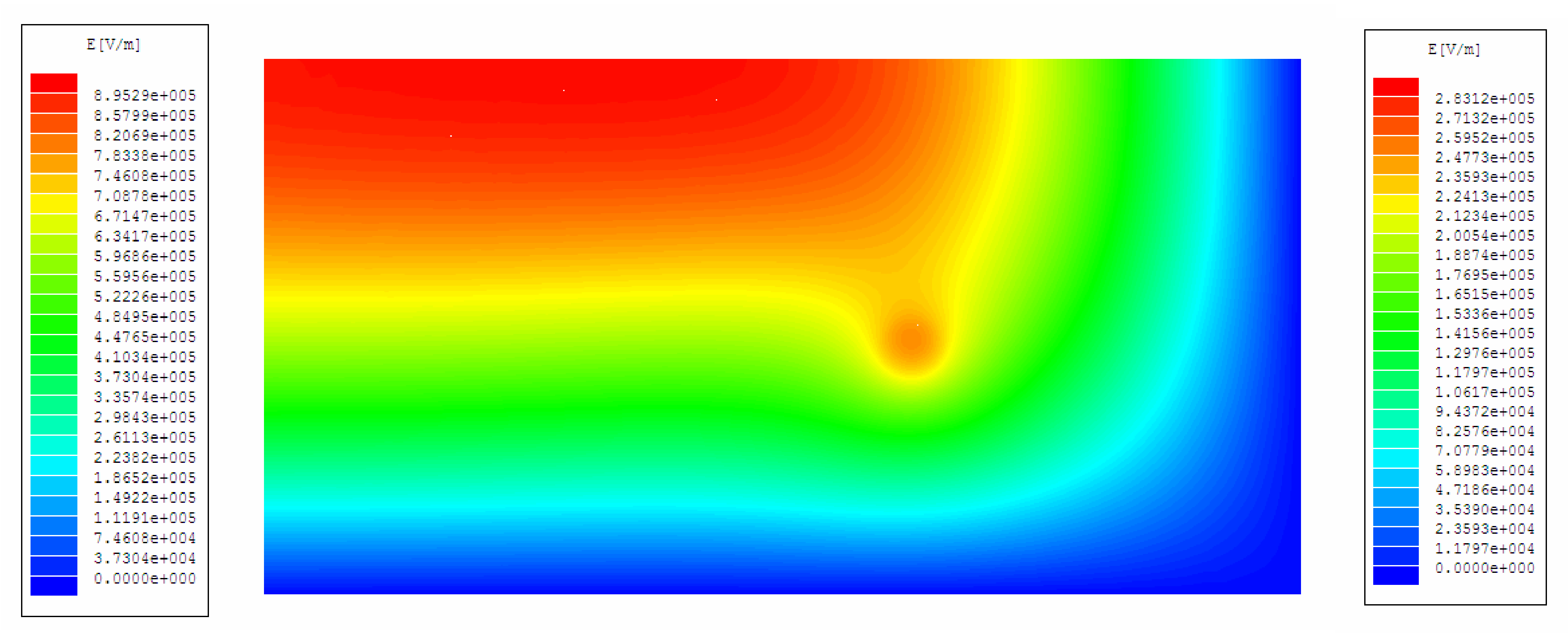
(Eps = 20, tg =1)

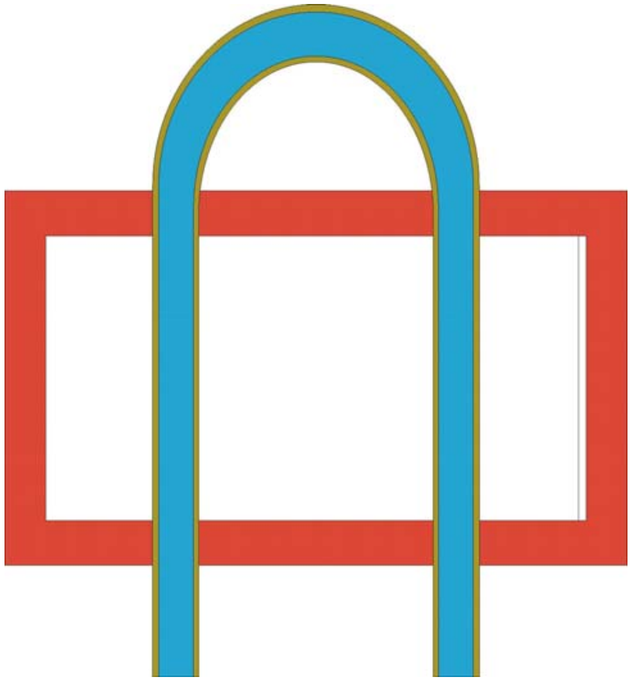



S_1 : S[port1:m1, port1:m1] (mag)
Plot 1 : S Matrix Data
-5
-10
-15
-20
-25
-30
-35
-40
-45
Magnitude (dB)
1
1.1
1.2
1.3
1.4
1.5
1.6
Frequency (GHz)

5MW

500kW

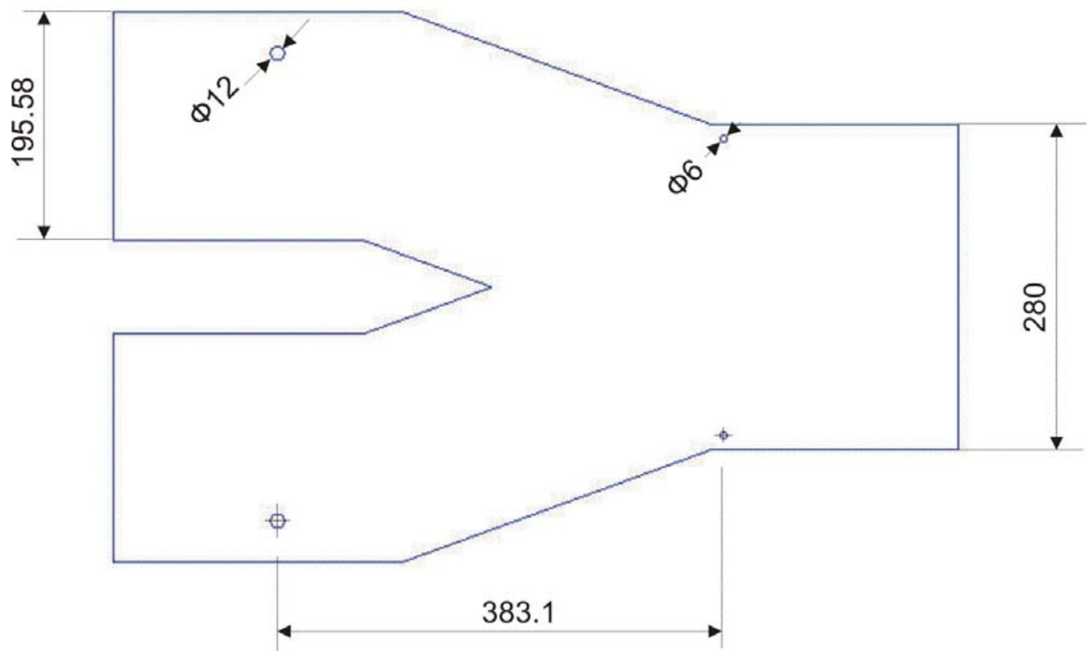

E [V/m]
8.9529e+005
8.5799e+005
8.2069e+005
7.8338e+005
7.4608e+005
7.0878e+005
6.7147e+005
6.3417e+005
5.9686e+005
5.5956e+005
5.2226e+005
4.8495e+005
4.4765e+005
4.1034e+005
3.7304e+005
3.3574e+005
2.9843e+005
2.6113e+005
2.2382e+005
1.8652e+005
1.4922e+005
1.1191e+005
7.4608e+004
3.7304e+004
0.0000e+000
E [V/m]
2.8312e+005
2.7132e+005
2.5952e+005
2.4773e+005
2.3593e+005
2.2413e+005
2.1234e+005
2.0054e+005
1.8874e+005
1.7695e+005
1.6515e+005
1.5336e+005
1.4156e+005
1.2976e+005
1.1797e+005
1.0617e+005
9.4372e+004
8.2576e+004
7.0779e+004
5.8983e+004
4.7186e+004
3.5390e+004
2.3593e+004
1.1797e+004
0.0000e+000



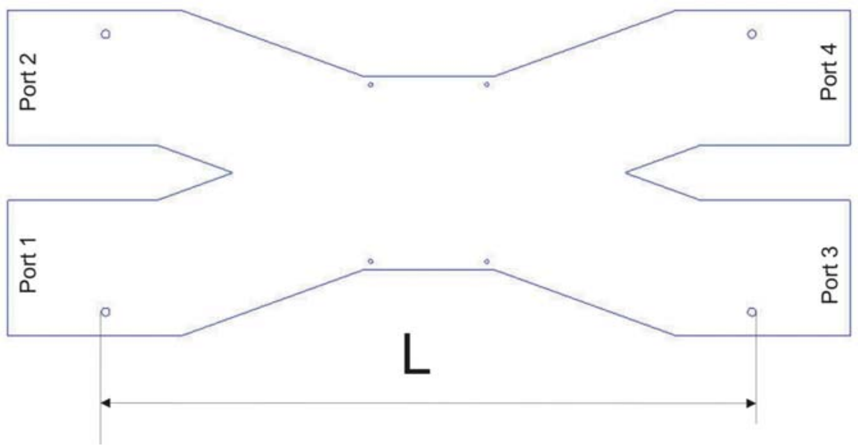
1. We don’t know property of water, but it can be measured experimentally.
2. More pipes gives less fields and wider passband.

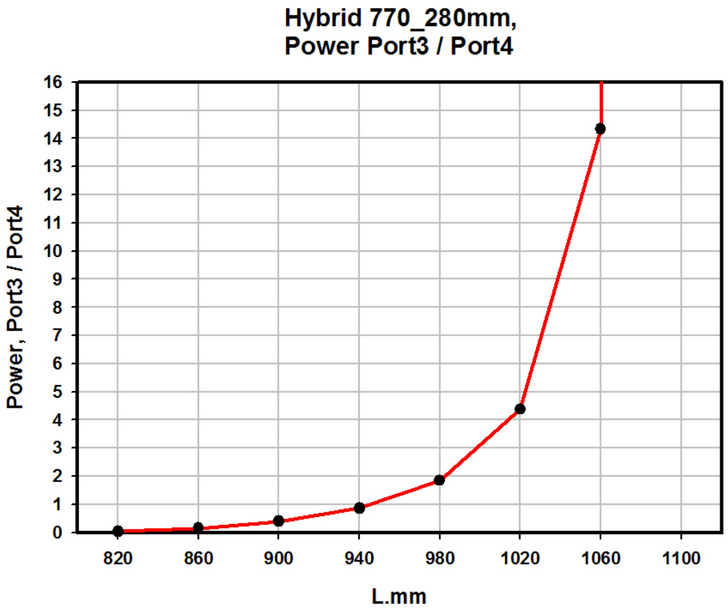
WR770 Elements

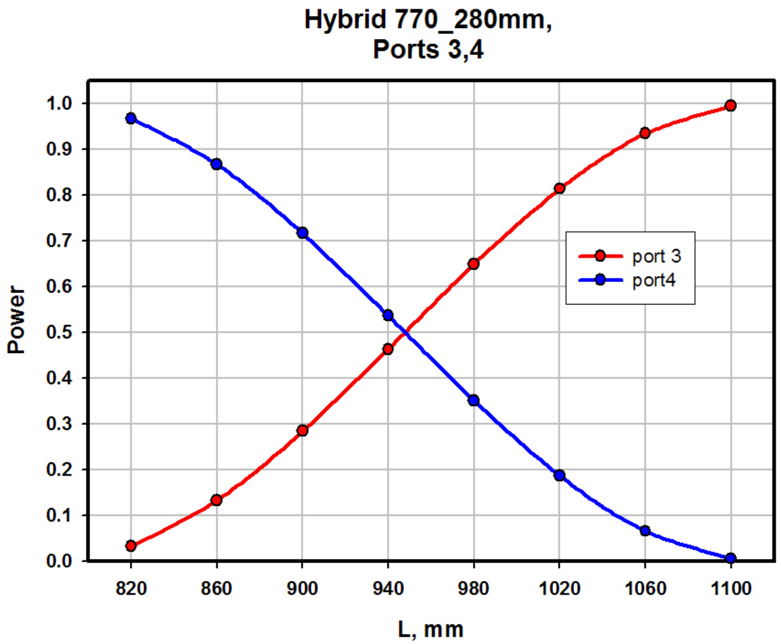
WR770 semi-hybrid

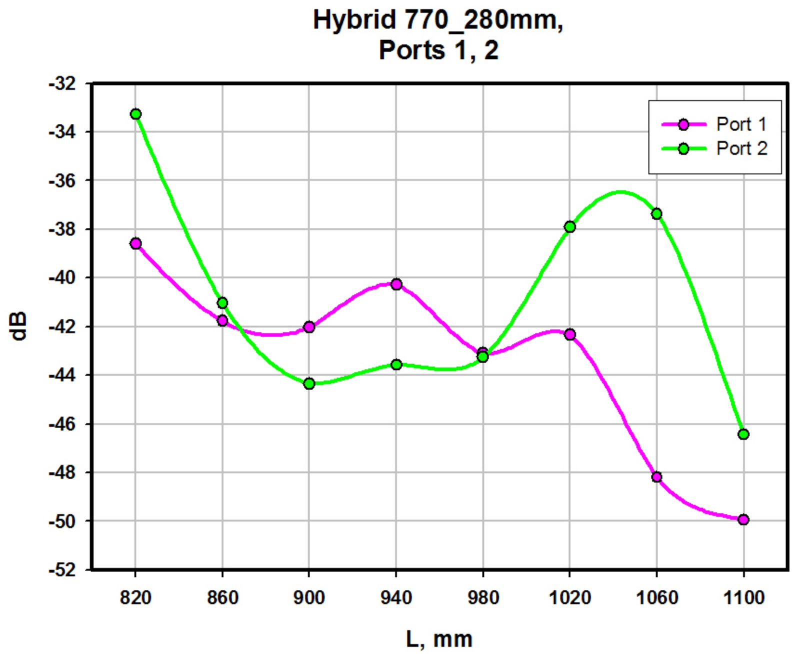


	port1:m1	port2:m1	port3:m1
port1:m1	(0.00298, 12.721)	(0.00909, -91.126)	(0.70708, 80.988)
port2:m1	(0.00909, -91.126)	(0.00298, 12.641)	(0.70708, 80.988)
port3:m1	(0.70708, 80.988)	(0.70708, 80.988)	(0.00887, 54.054)
port3:m2	(0.70707, 98.455)	(0.70707, -81.545)	(2.17559e-006,-111.398)

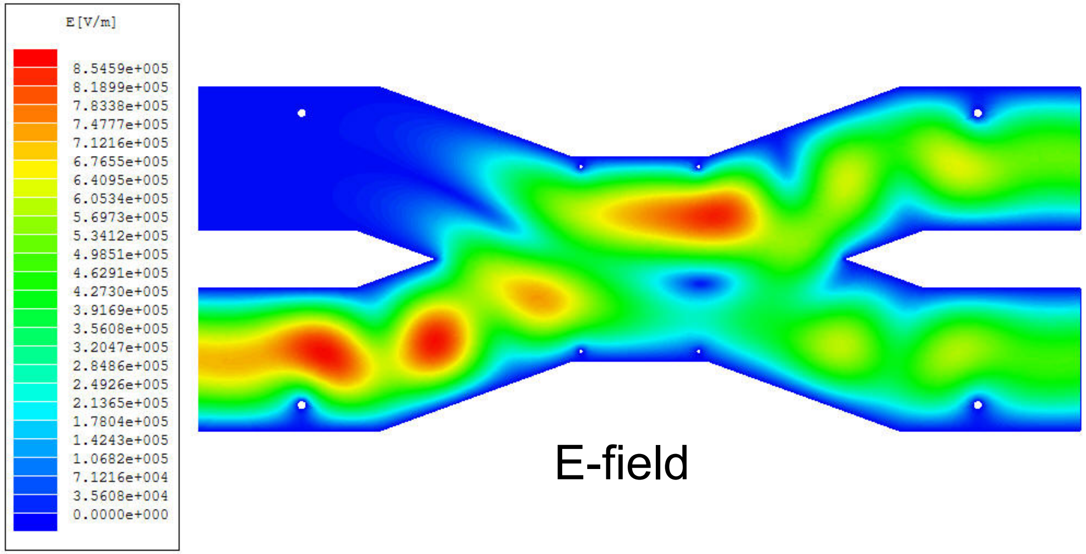

Port 2
Port 4
Port 1
Port 3
L


Hybrid 770_280mm,
Power Port3 / Port4
Power, Port3 / Port4
L.mm

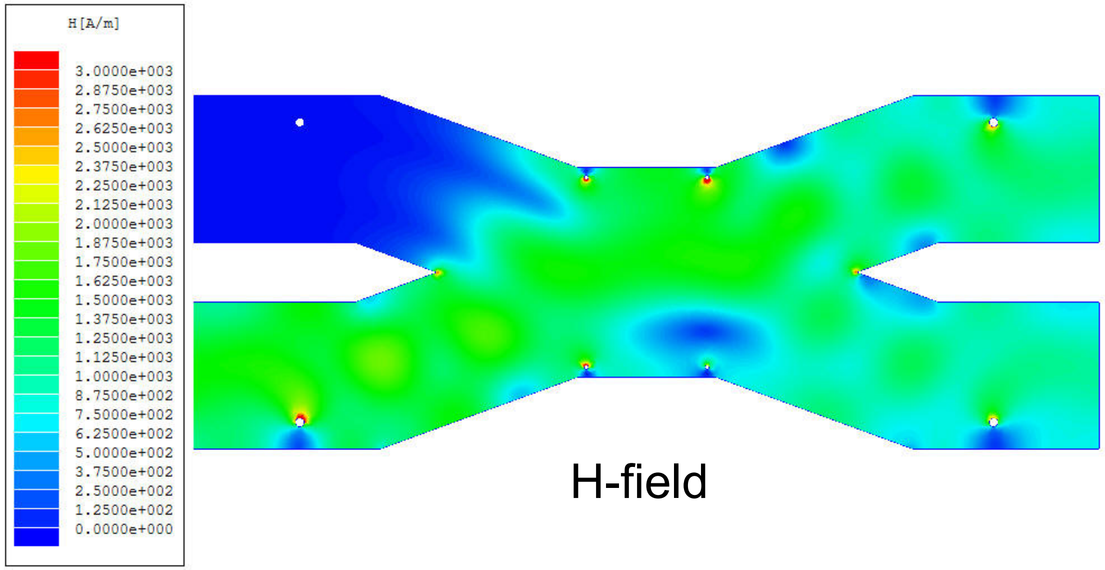

Hybrid 770_280mm,
Ports 3,4
port 3
port4
Power
L, mm


Hybrid 770_280mm,
Ports 1, 2
Port 1
Port 2
dB
L, mm

Fields for 5MW

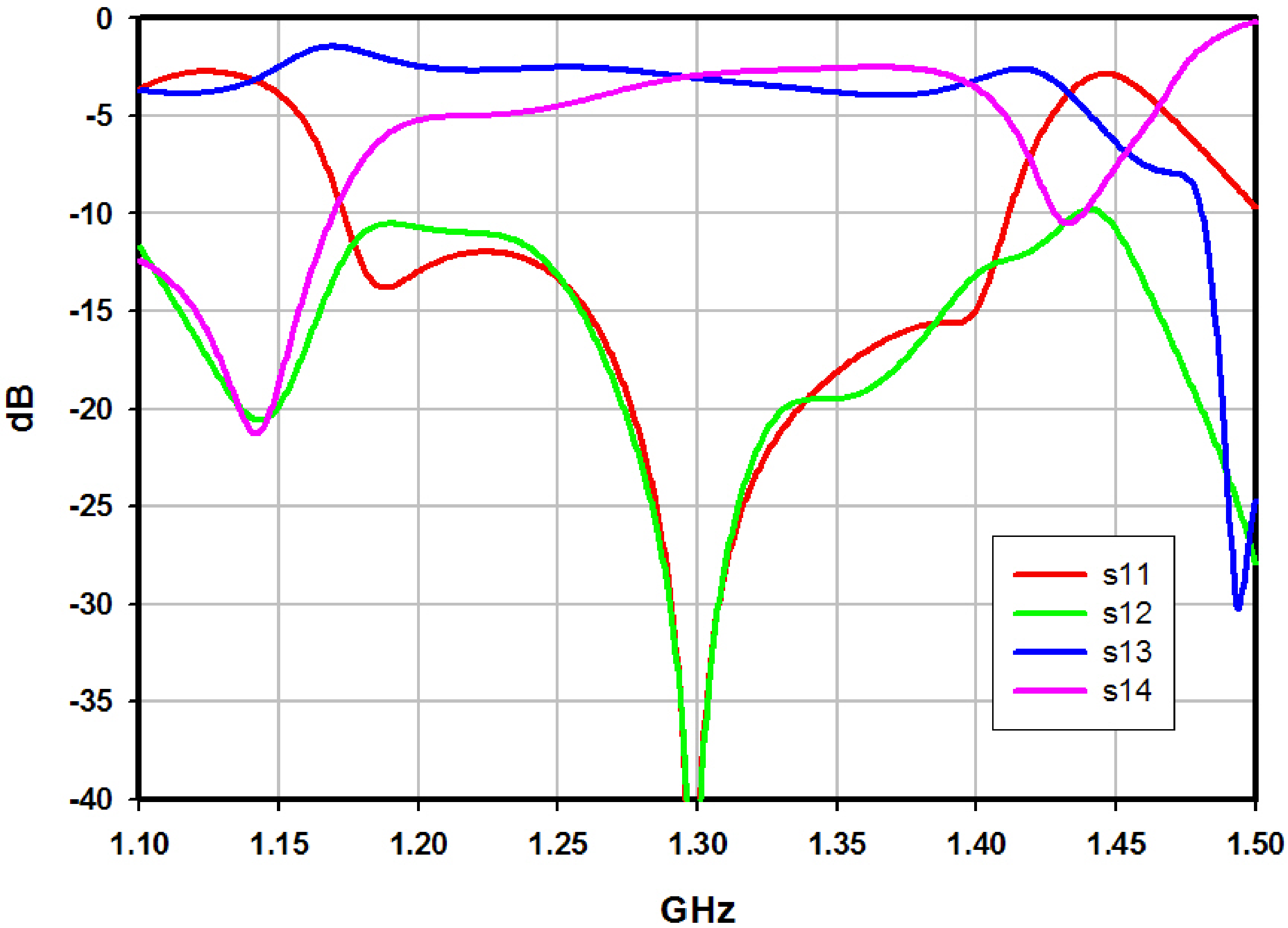


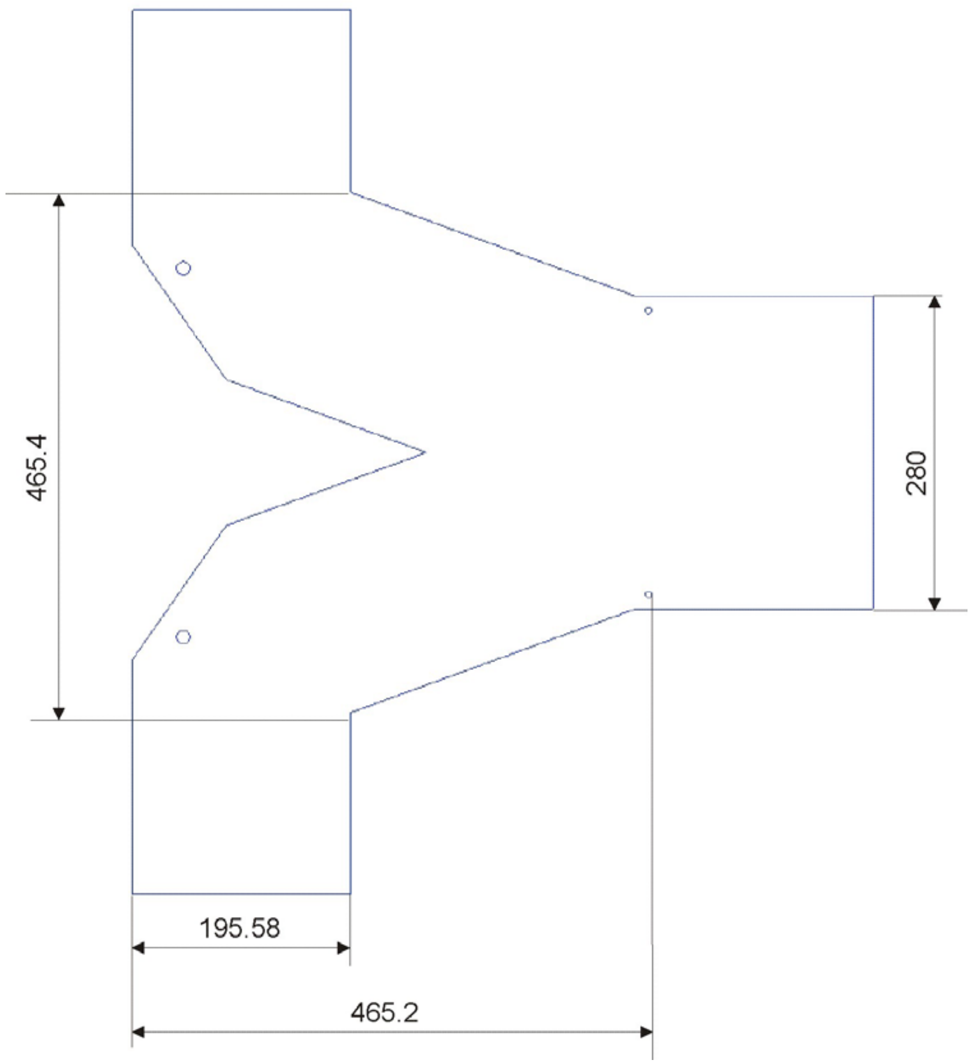
E-field



H-field

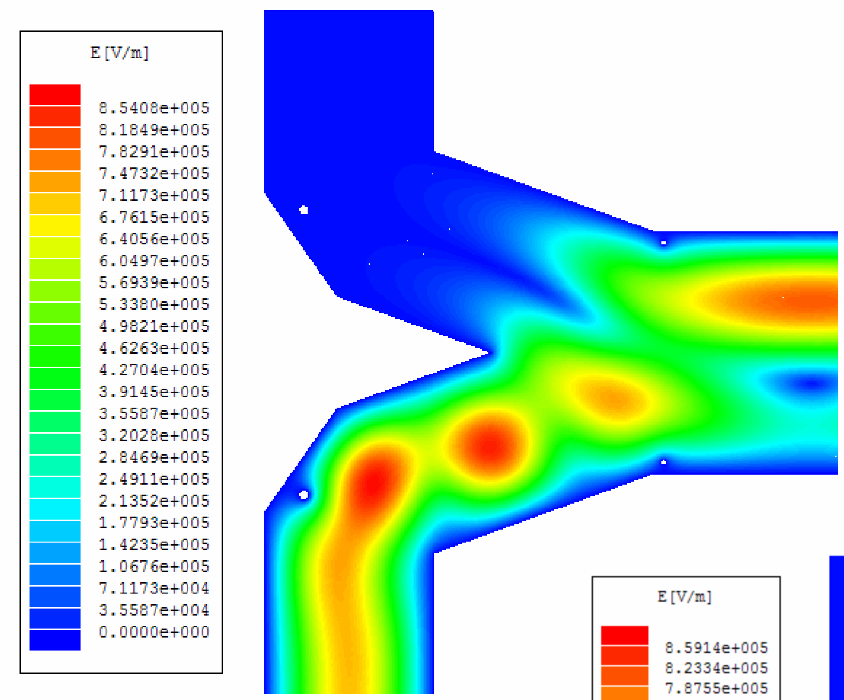
Hybrid 770_280mm, Example of passband

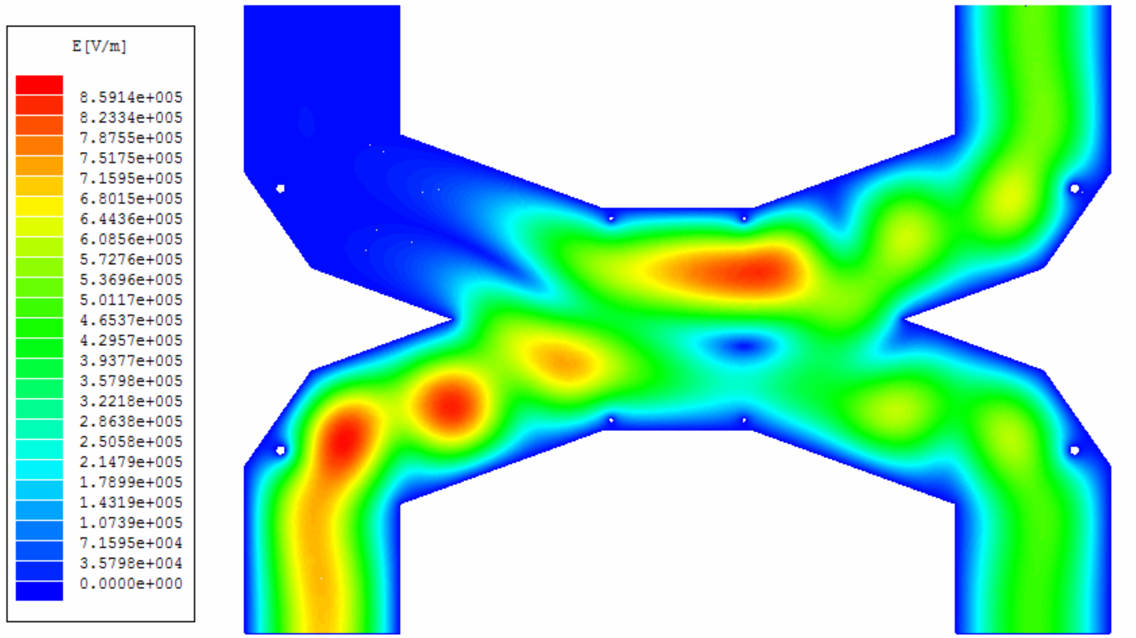


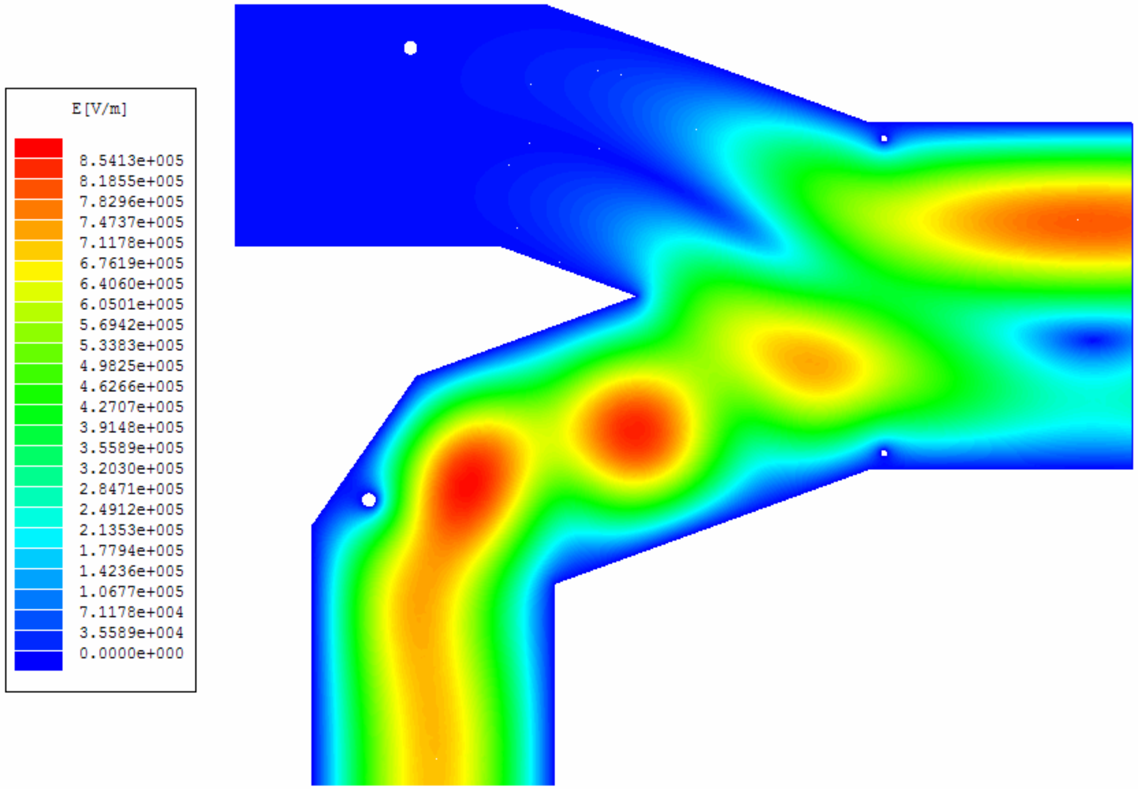


	port1:m1	port2:m1	port3:m1	port3:m2
port1:m1	(0.00375,-139.527)	(0.00774, 173.187)	(0.70710,-167.633)	(0.70707, 28.095)
port2:m1	(0.00774, 173.187)	(0.00375,-139.480)	(0.70709, 12.368)	(0.70707, 28.096)
port3:m1	(0.70710,-167.633)	(0.70709, 12.368)	(0.00589,-120.525)	(1.58242e-006,-103.601)
port3:m2	(0.70707, 28.095)	(0.70707, 28.096)	(1.58242e-006,-103.601)	(0.01065, 48.002)

E –fields for 5 MW







	port1:m1	port2:m1	port3:m1	port3:m2
port1:m1	(0.00385,-139.305)	(0.00314, -39.746)	(0.70583, 11.935)	(0.70837, 28.519)
port2:m1	(0.00314, -39.746)	(0.00309, 11.932)	(0.70838, -98.575)	(0.70582, 98.009)
port3:m1	(0.70583, 11.935)	(0.70838, -98.575)	(0.00143, 43.309)	(0.00052, 39.190)
port3:m2	(0.70837, 28.519)	(0.70582, 98.009)	(0.00052, 39.190)	(0.00644, -0.818)

Shell we use two WR770 instead three WR650?

Electric fields: WR770, 5MW – 7.0 kV/cm
WR650, 3.3MW – 7.2 kV/cm