

New phase-shifter and Variable Hybrid

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**TILC 09
April 20, Tsukuba, Japan**

New phase shifter, motivation:

To have simple cheap reliable phase shifter.

Phase shifter has to stand the numerous breakdowns – no dielectric.

Design task:

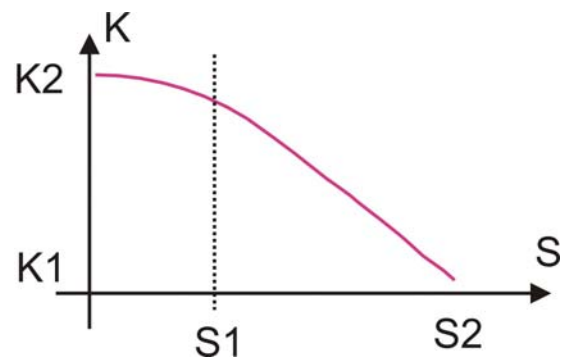
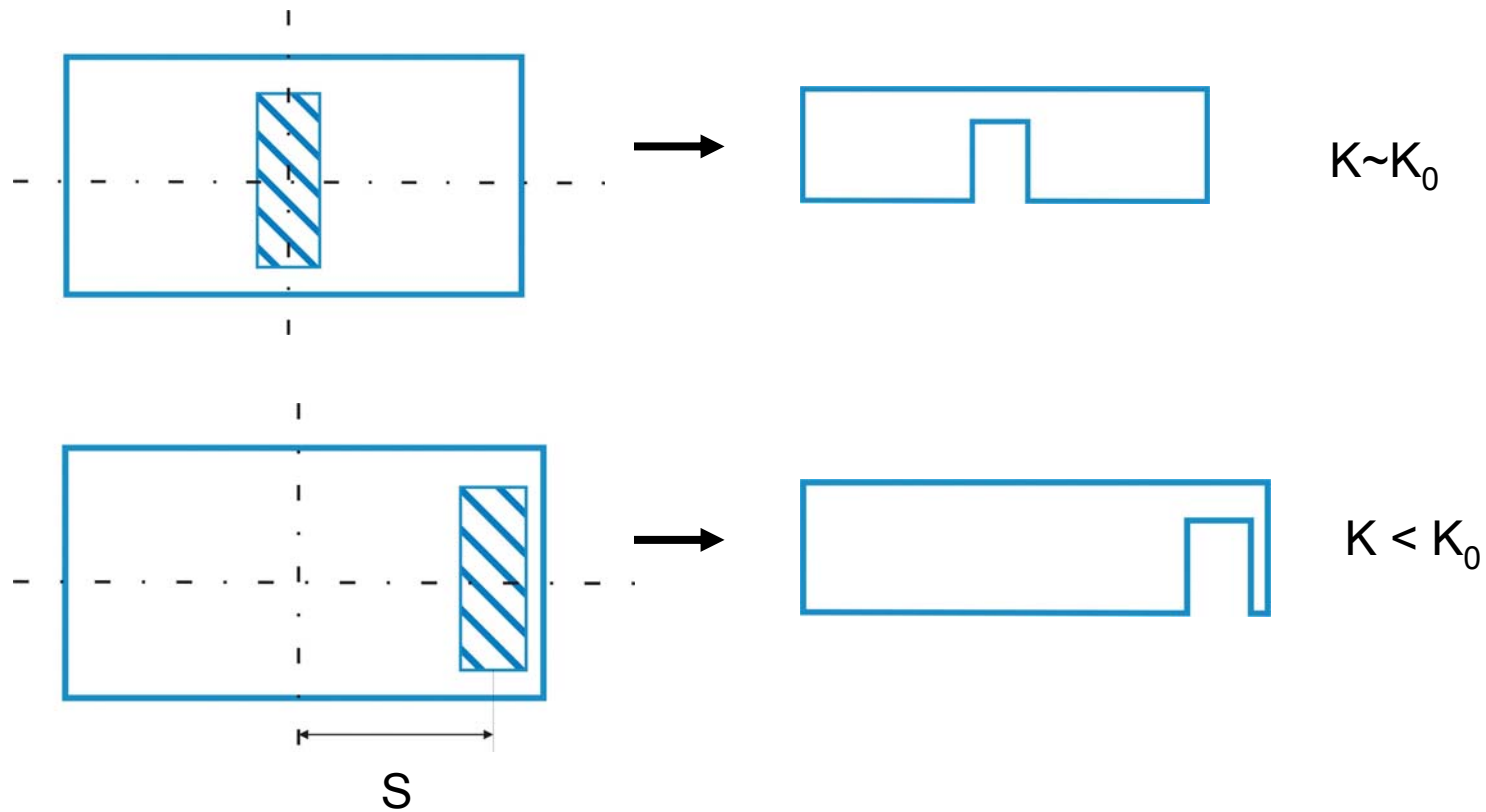
Phase shift $> 90^\circ$

Power (for short) > 500 kW

SWR < 1.2

Reasonable length ~ 0.5 m

Simple



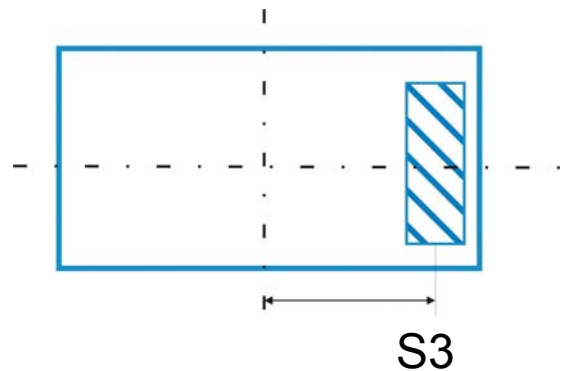
$S < S_1$ - not effective region

$S > S_1$ - effective region

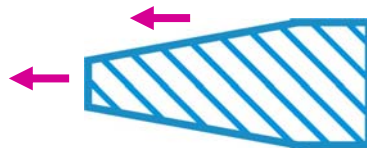
How to provide very low reflection ($R < 0.05$) level for any position of insert ?



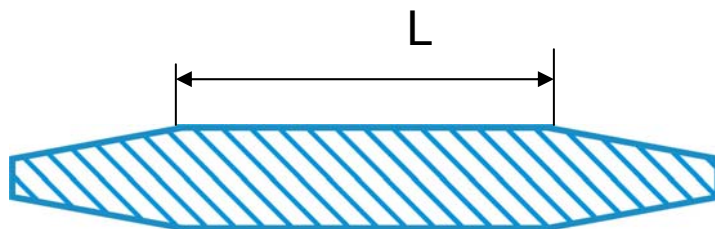
- Fin must have special shape



Fortunately the reflections are small ($R < 0.03$) for any shape at position S3

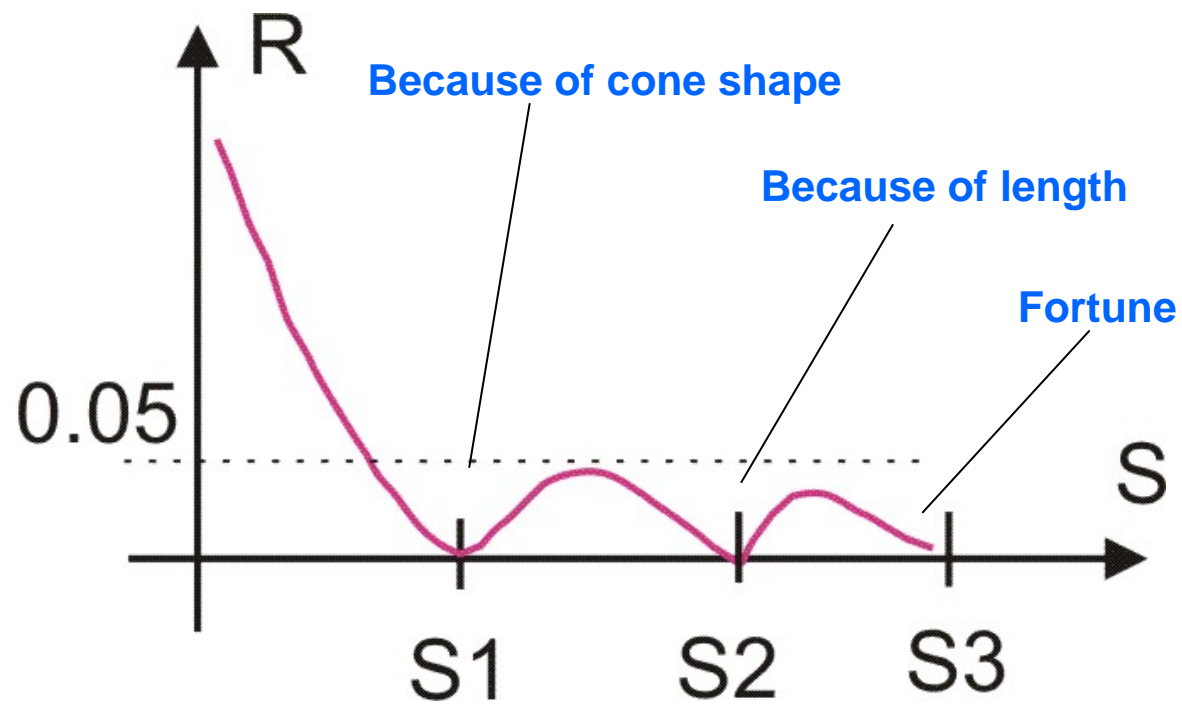


We can find special cone, which has no reflection at position S1 – reflection from nose is compensated by reflection from slope

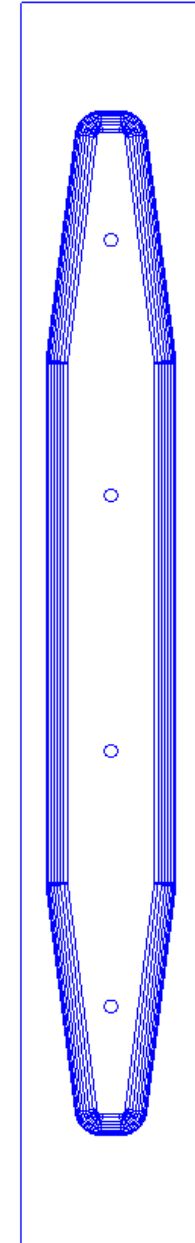
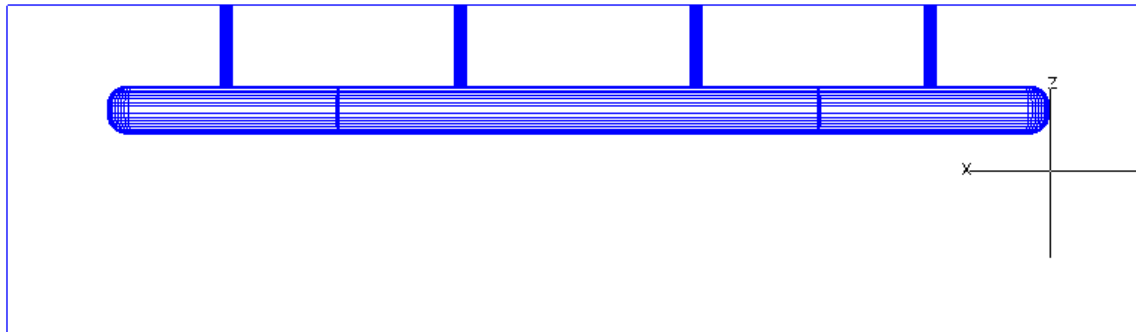
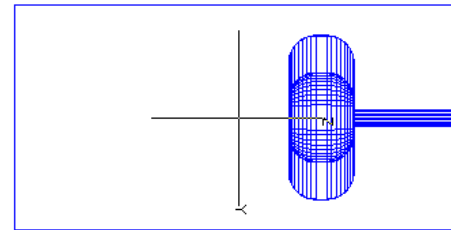
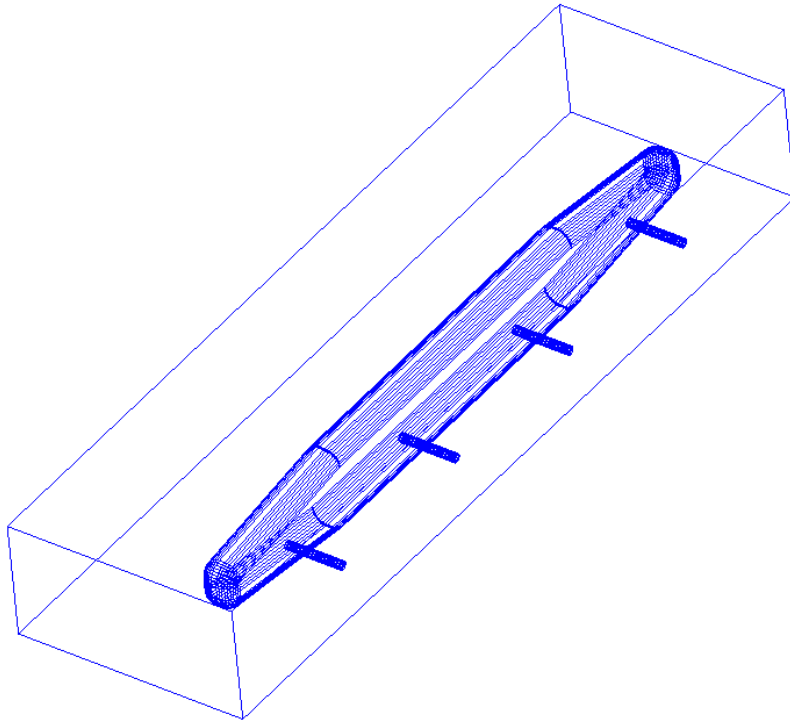


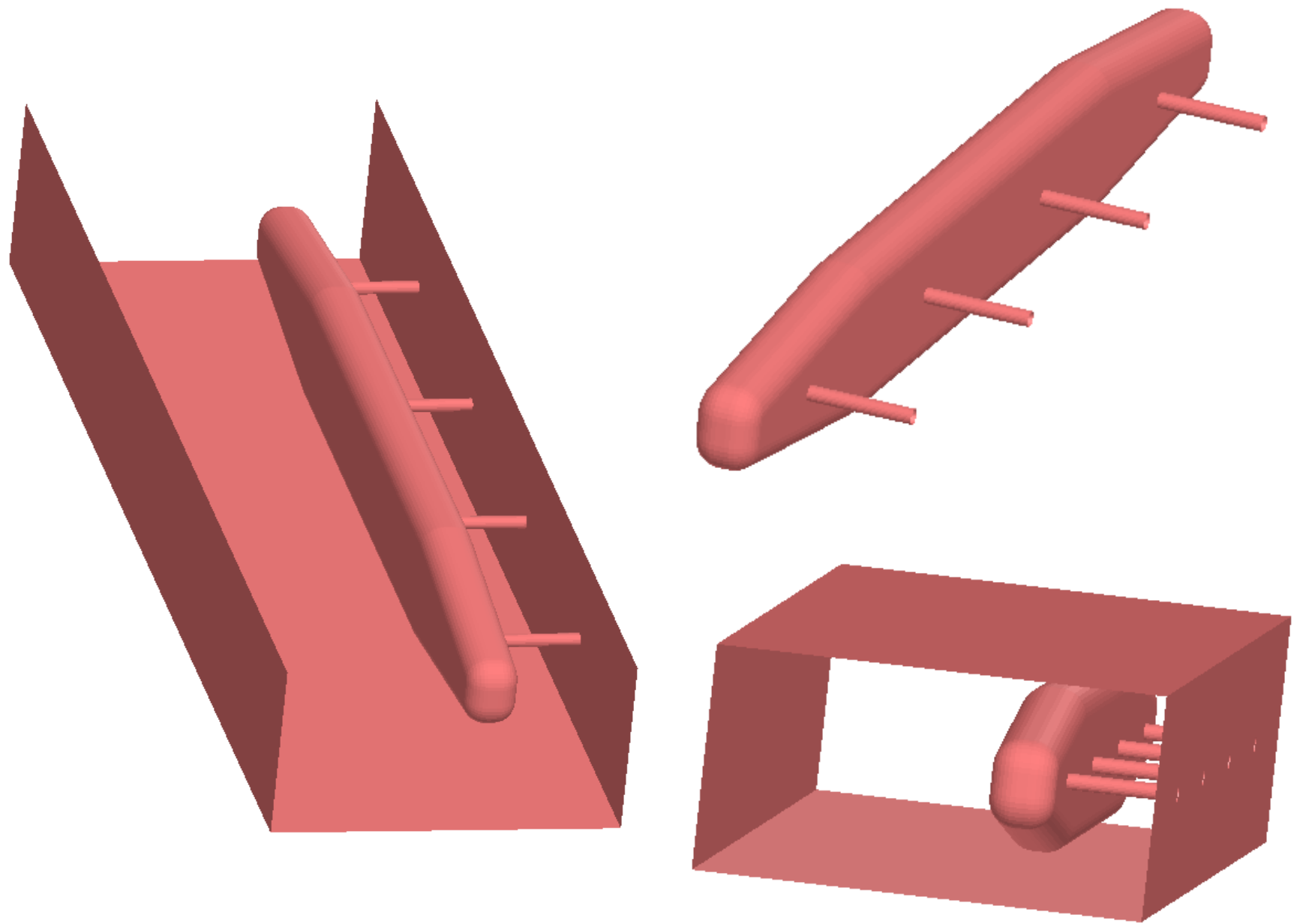
We can find special length L, which provide no reflection for position S2. $S1 < S2 < S3$

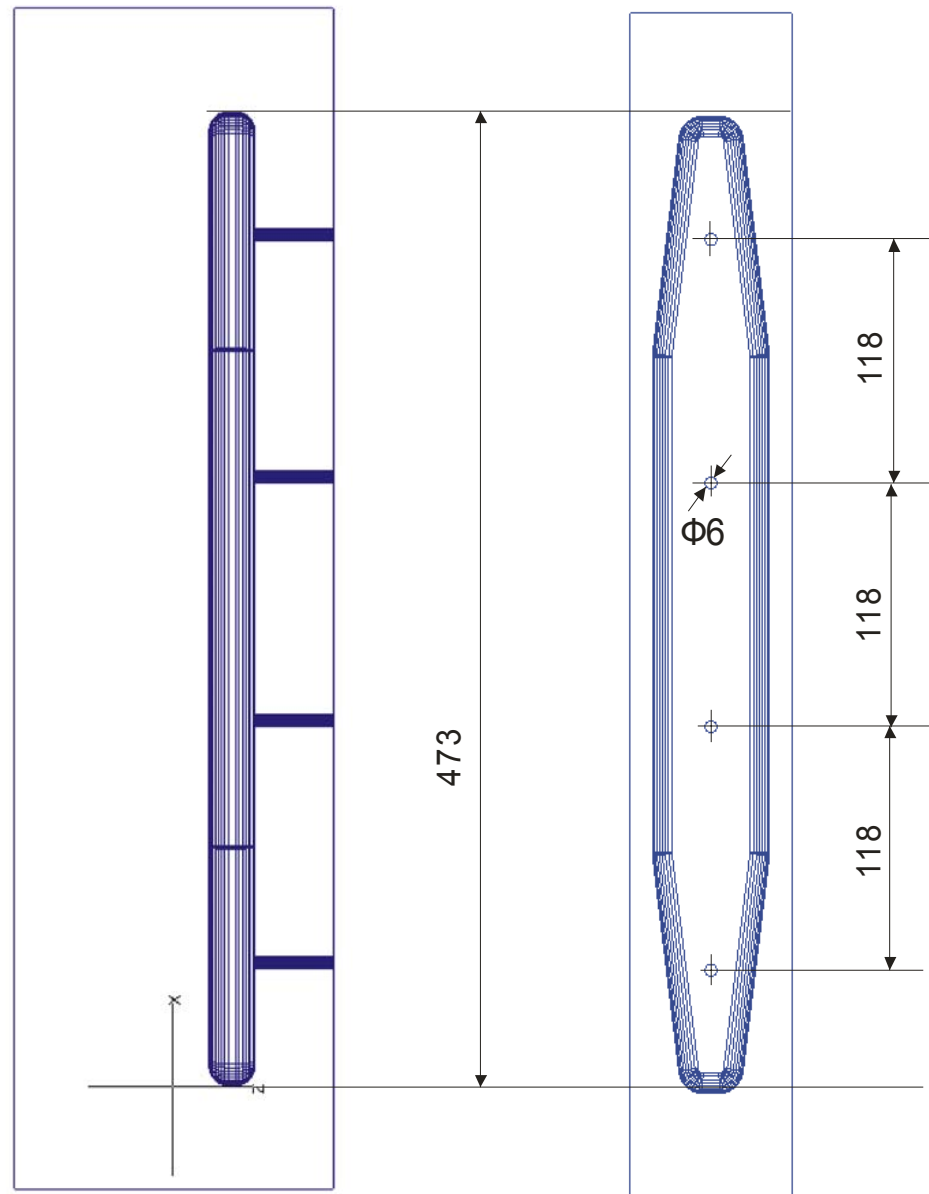
We can get three zero-point in working range of fin position:

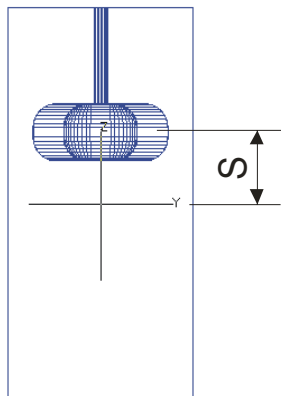


Real shape

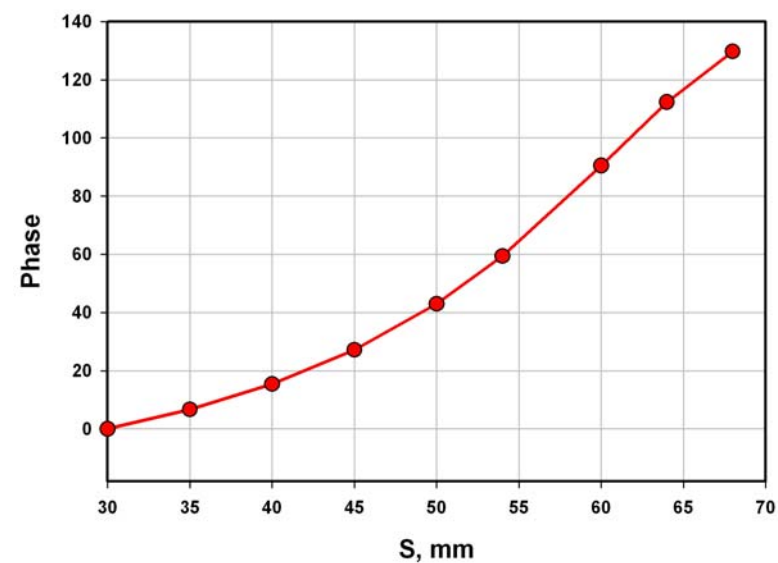




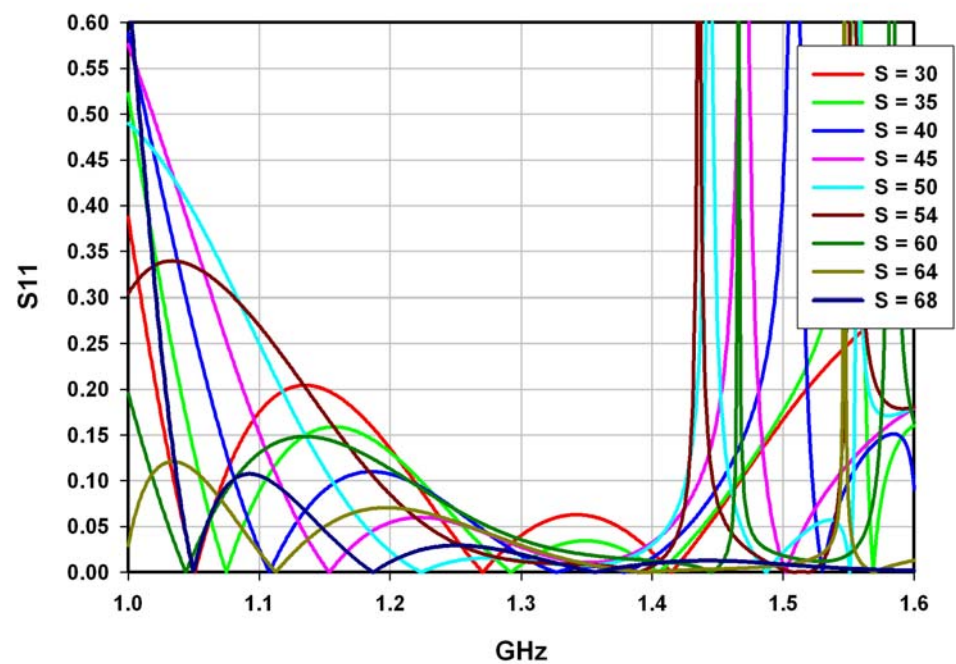


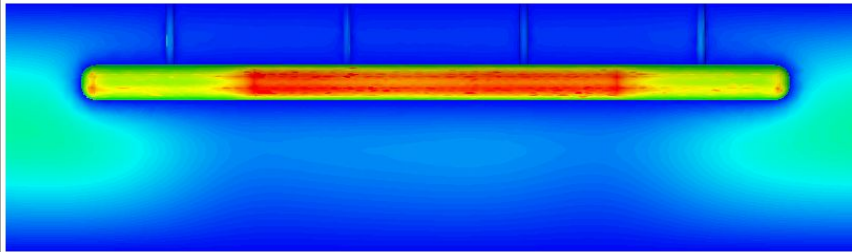
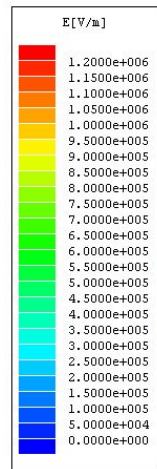


Phase shift vs S



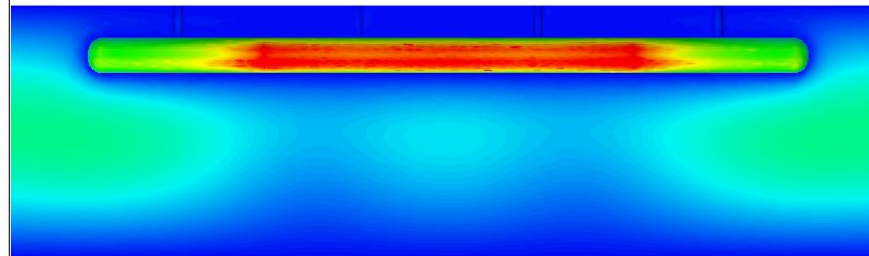
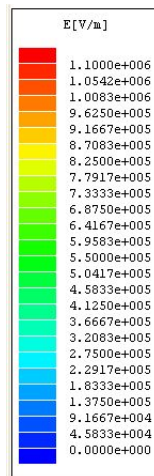
Phase shifter,
S11 for different displacement S



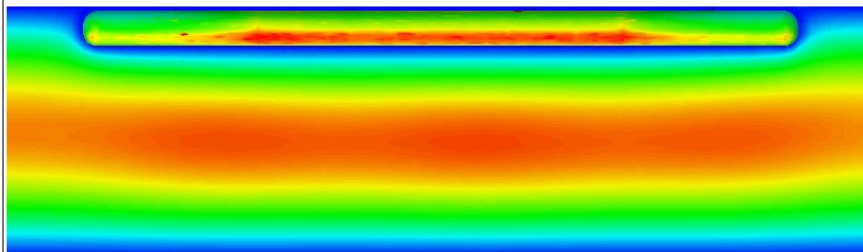
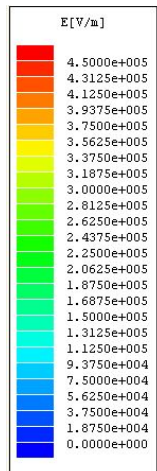


P = 1 MW

S = 30mm

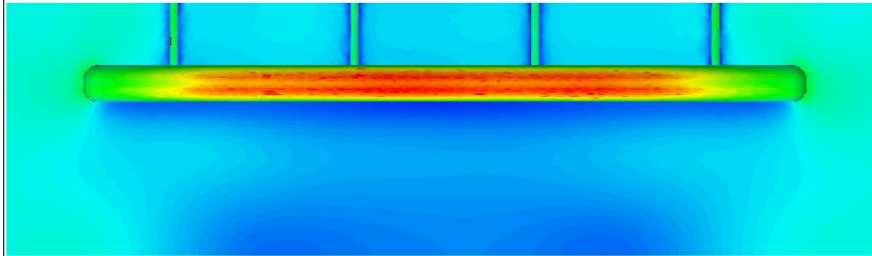
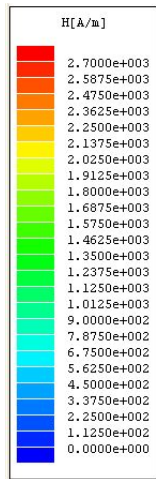


S = 50mm



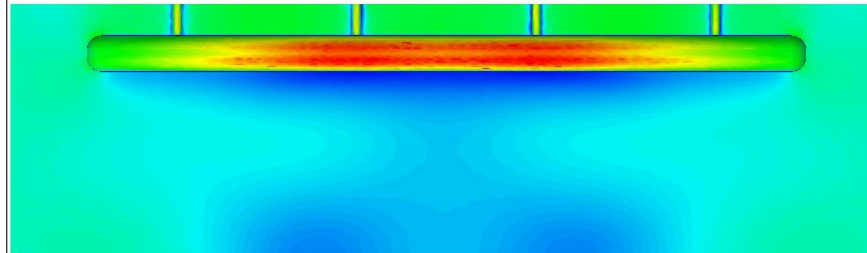
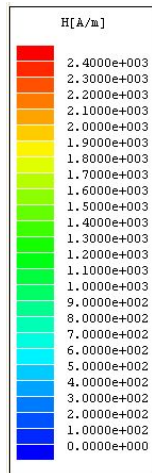
S = 68mm

Air breakdown limit = 5.5MW

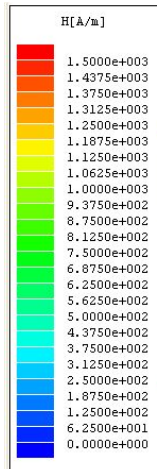


P = 1MW

S = 30mm



S = 50mm

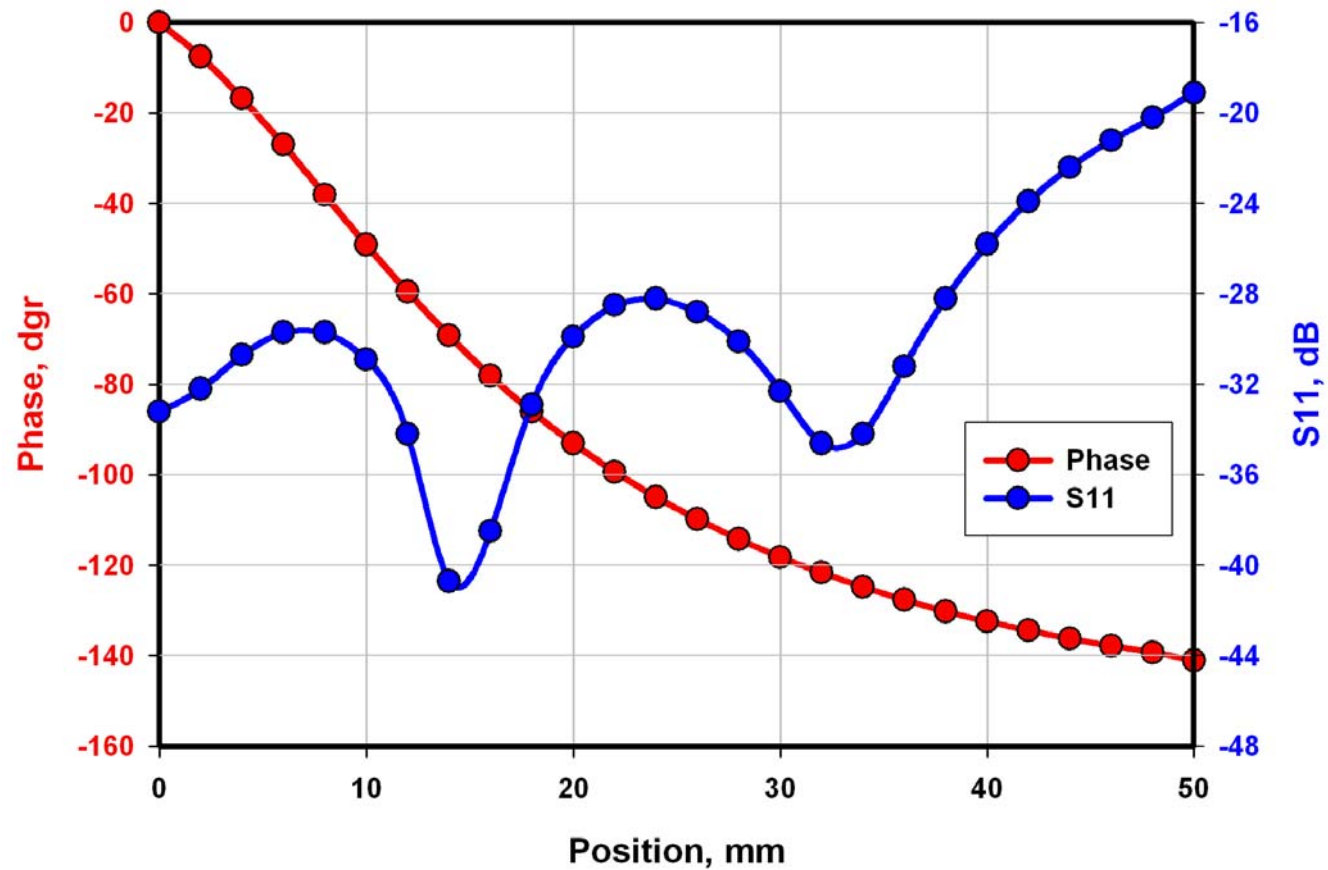


S = 68mm

Parameters of phase shifter:

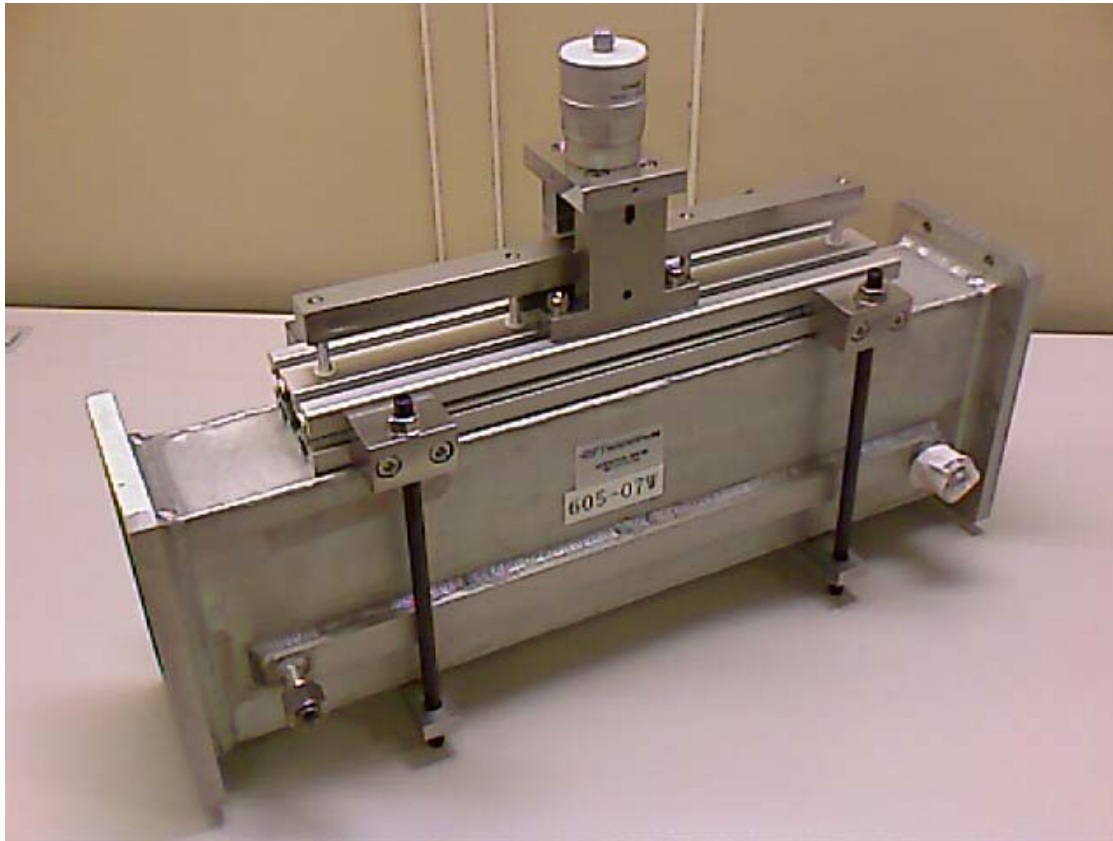
Phase shift (SWR <1.1)	130°
Air breakdown limit (mtch. load)	~5.5 MW
Length	~ 0.5 m

Cold measurements of new phase shifter

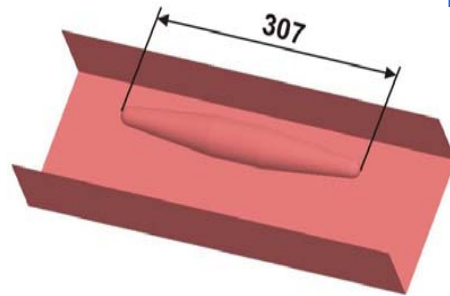


Phase shifter was tested till 2.9 MW (klystron limitation) without breakdowns

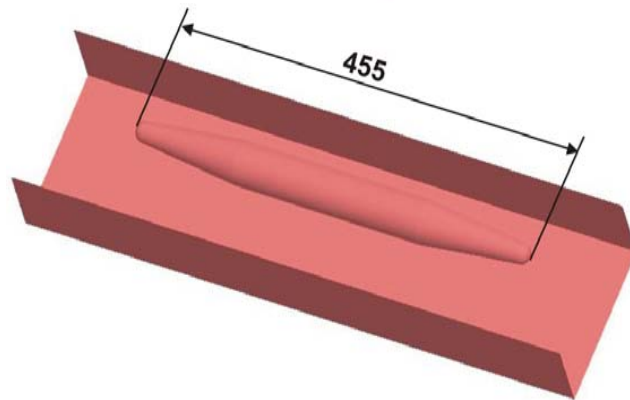
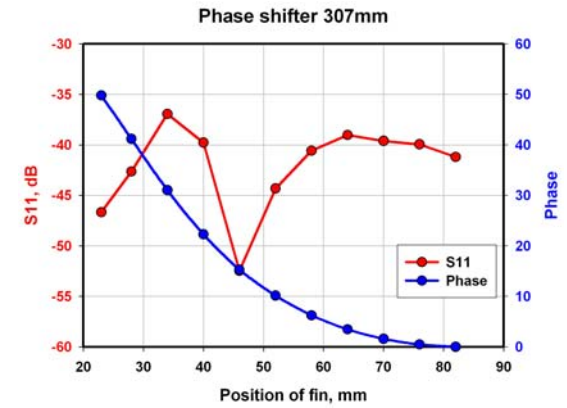
Phase shifter



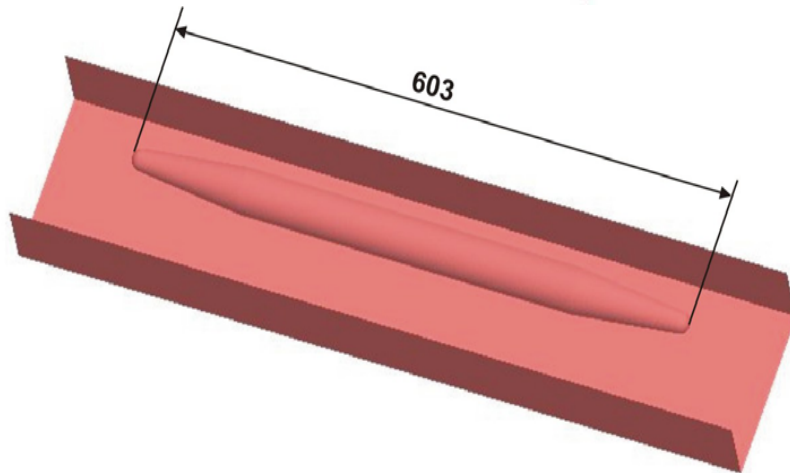
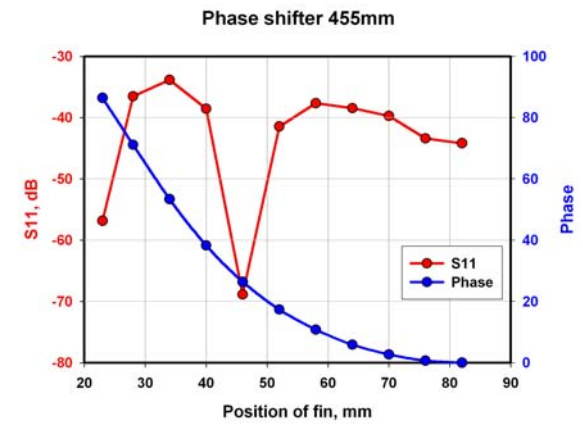
New design, $P_{\text{air}} = 12\text{MW}$ (!)



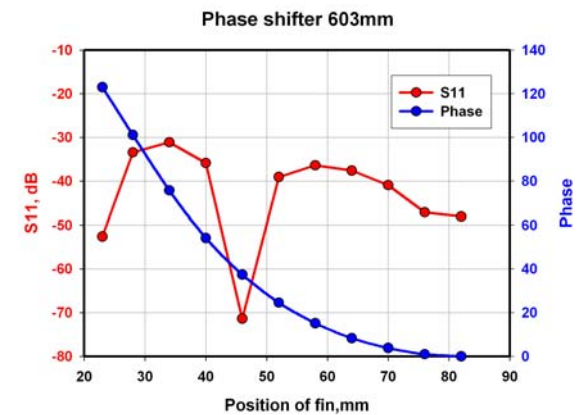
$$\Delta\phi = 50^\circ$$



$$\Delta\phi = 85^\circ$$



$$\Delta\phi = 120^\circ$$

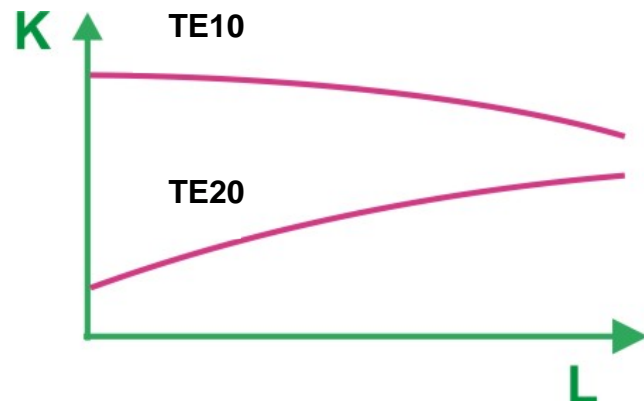
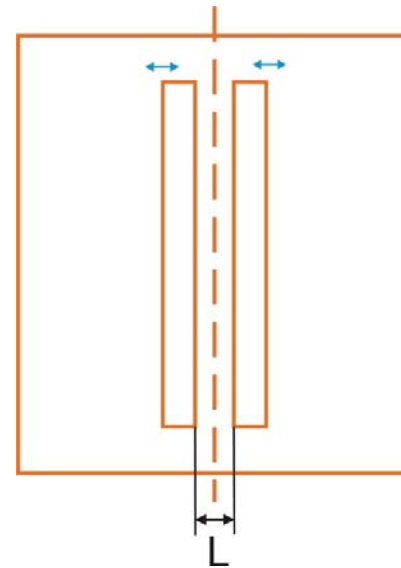


Based on this phase shifter we can build variable hybrid.

Idea:

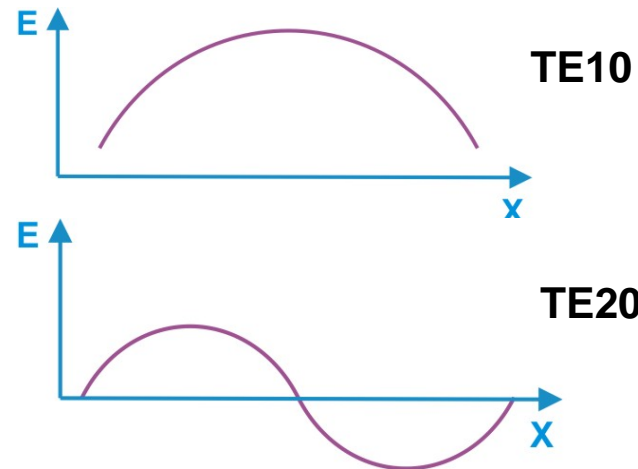


Geometry consist of two phase shifter



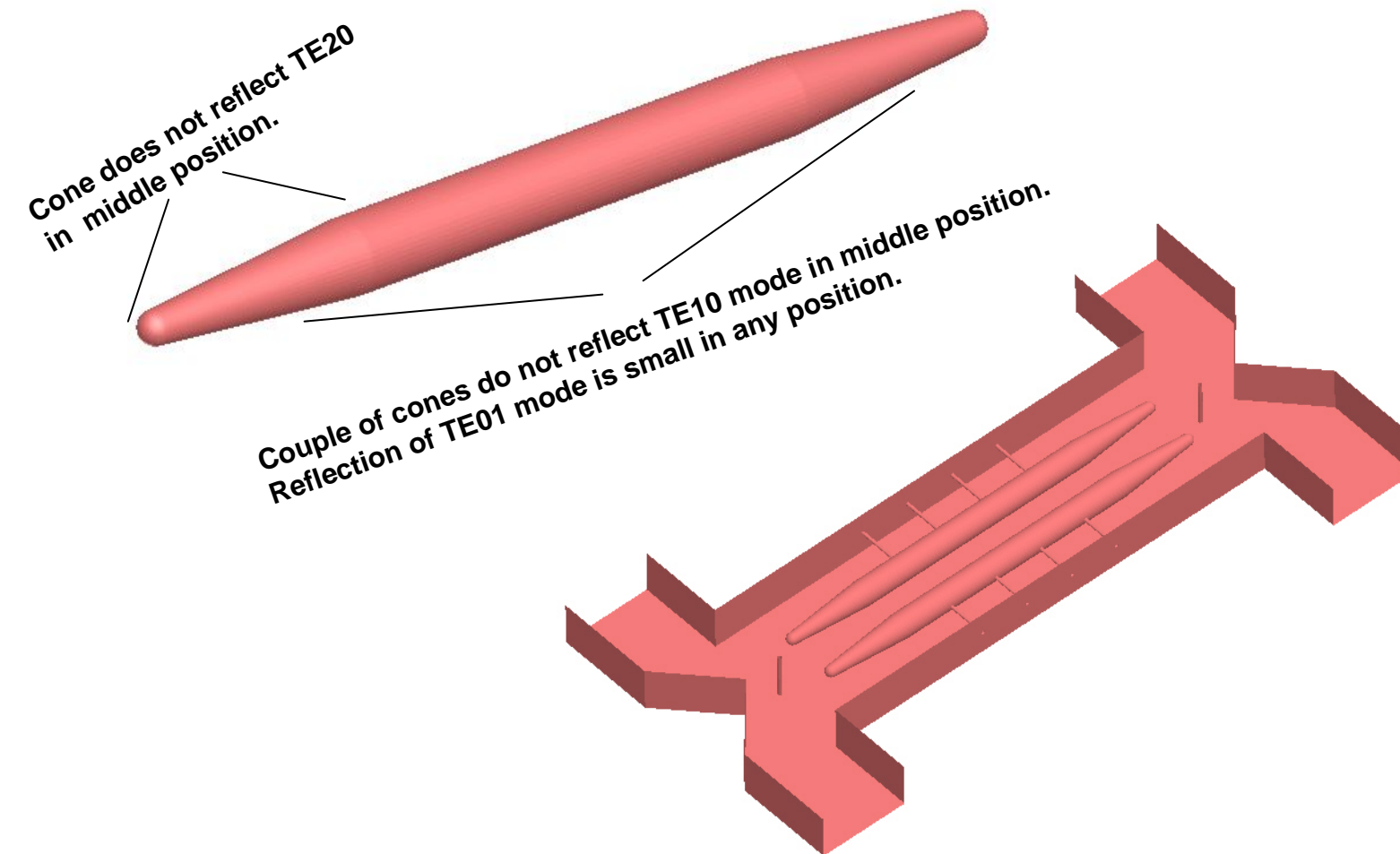
Wavelength of TE10 is not sensitive to L.
Wavelength of TE20 is rather sensitive.
We can change phase between TE10 and TE20 by changing L

Only two mode can propagate:

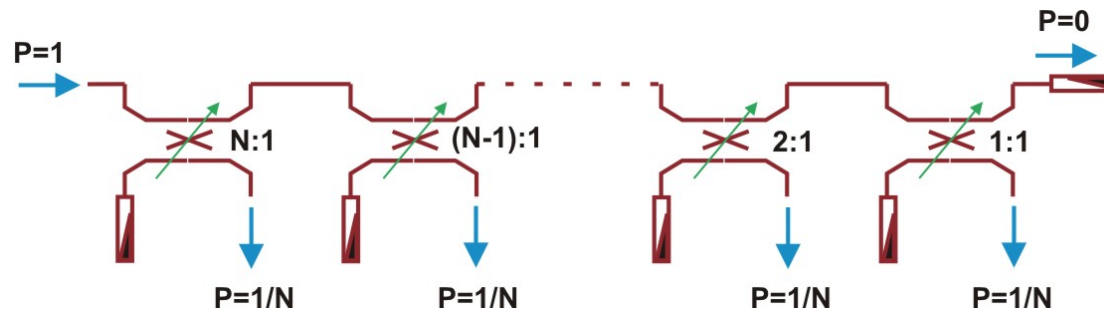


But now we have to match the fin for two modes – TE₁₀ and TE₂₀

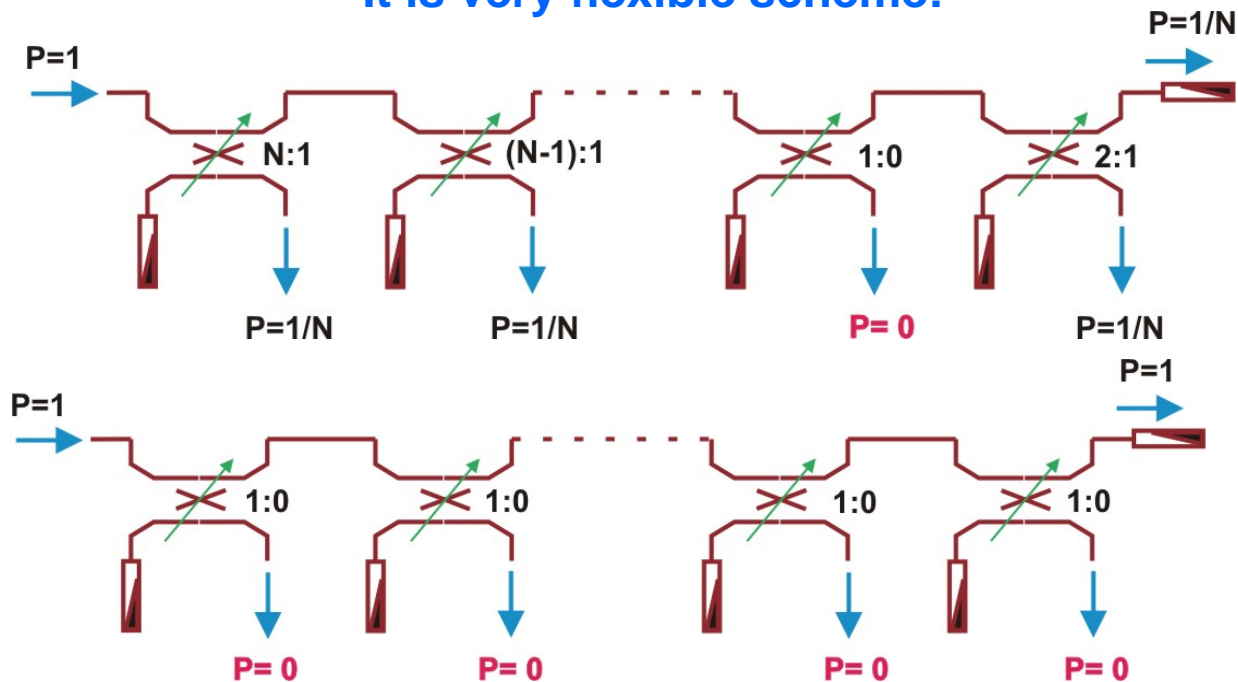
Fin was chosen cylindrical shape to increase the radius, to decrease electric field and to increase the maximum transmitted power



Possible scheme of power distribution:

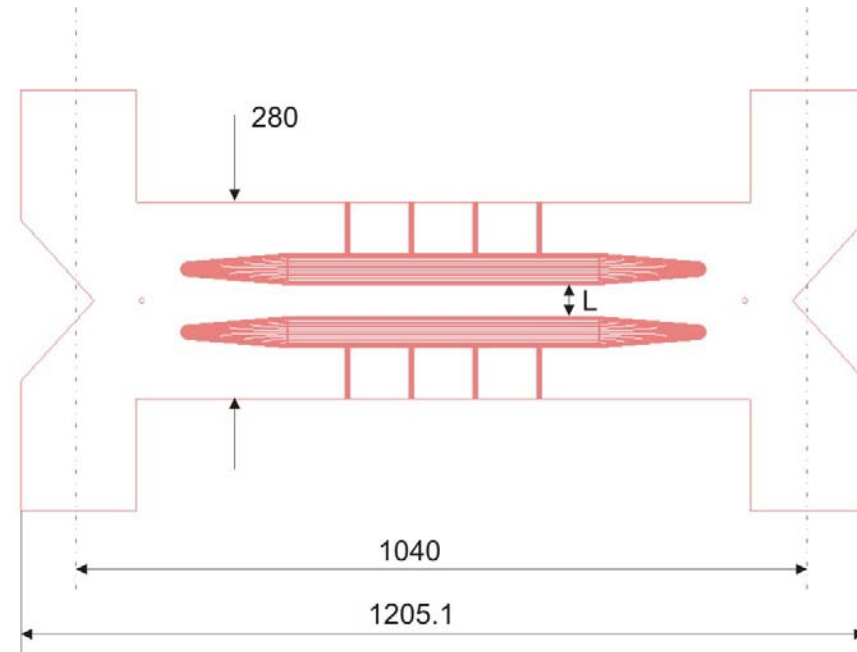
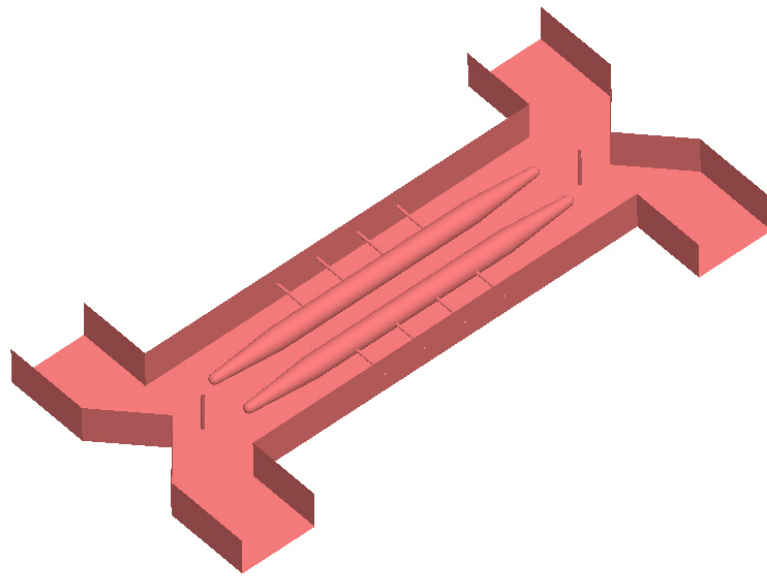


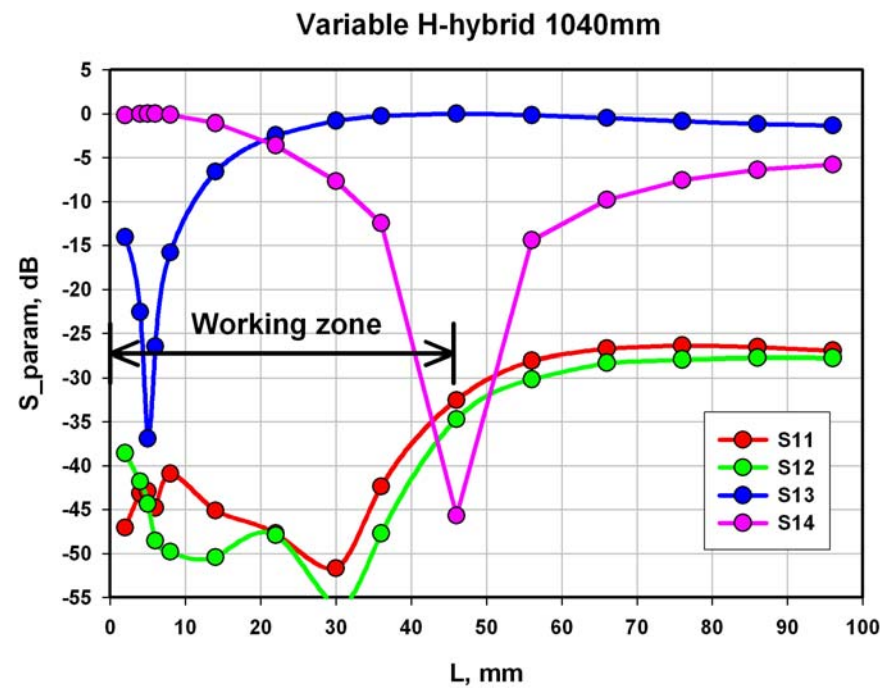
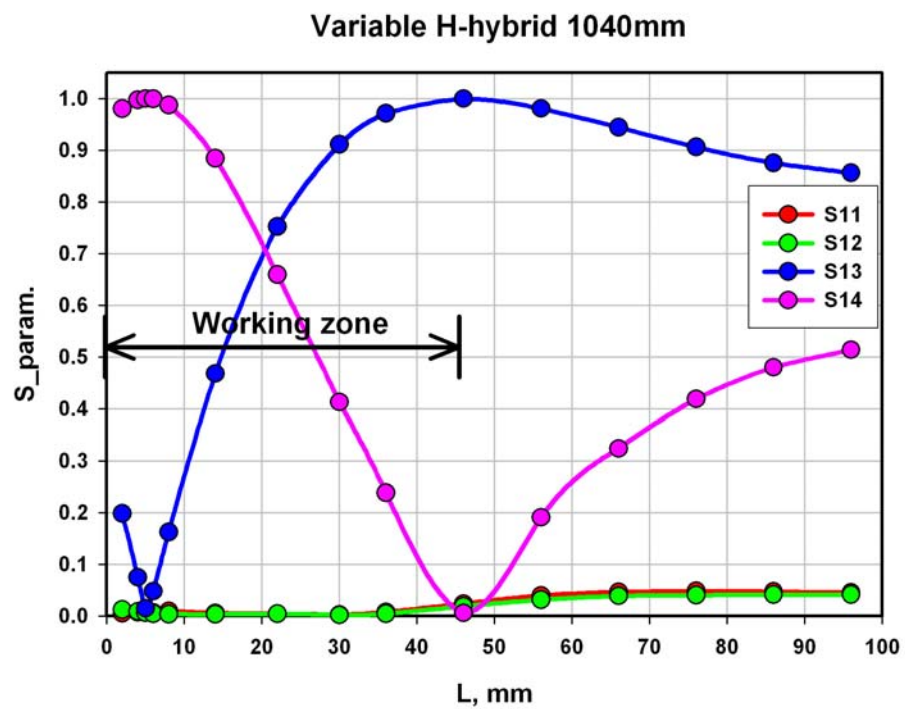
It is very flexible scheme:



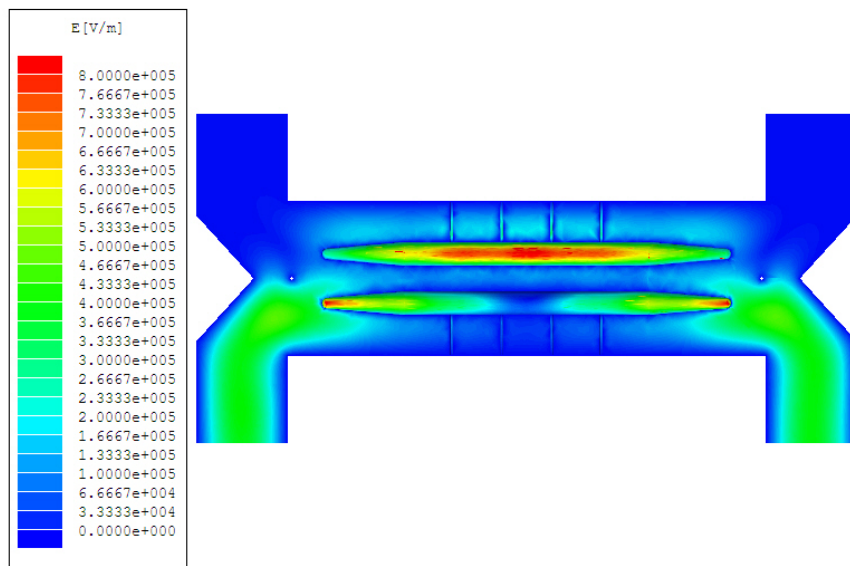
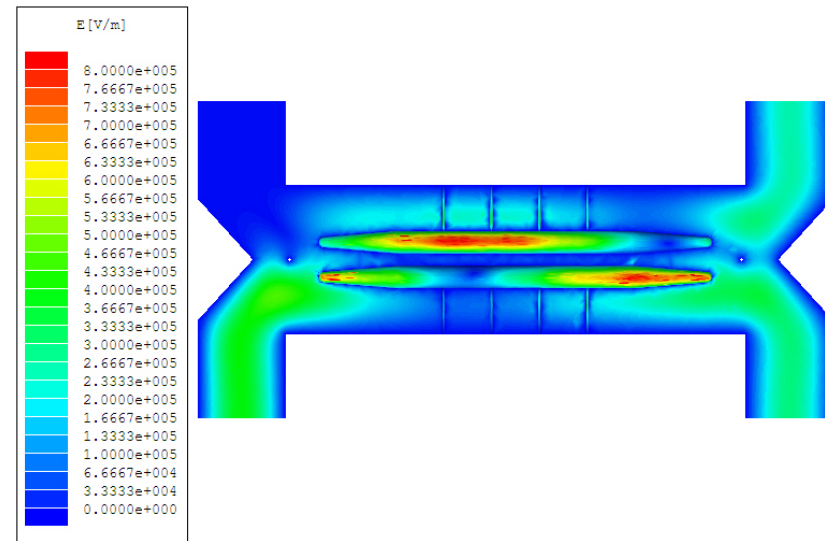
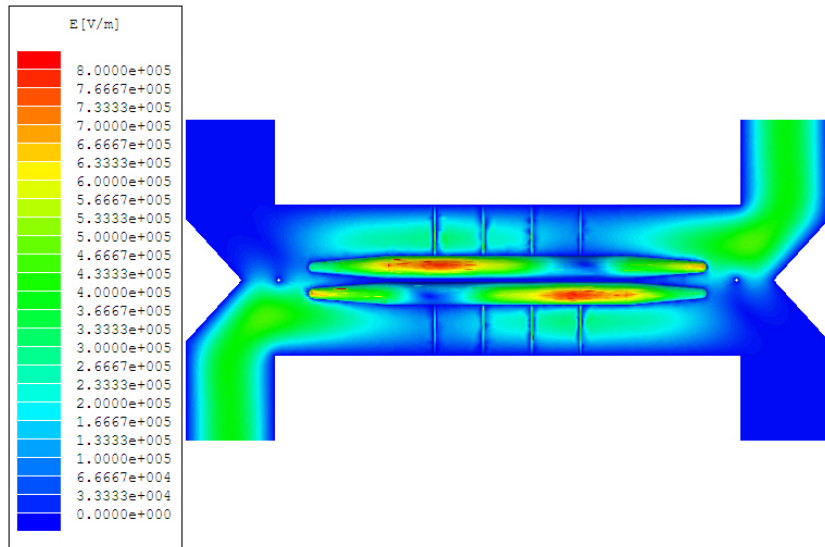
But it requires hybrids with full range of tuning

Hybrid with full range of tuning



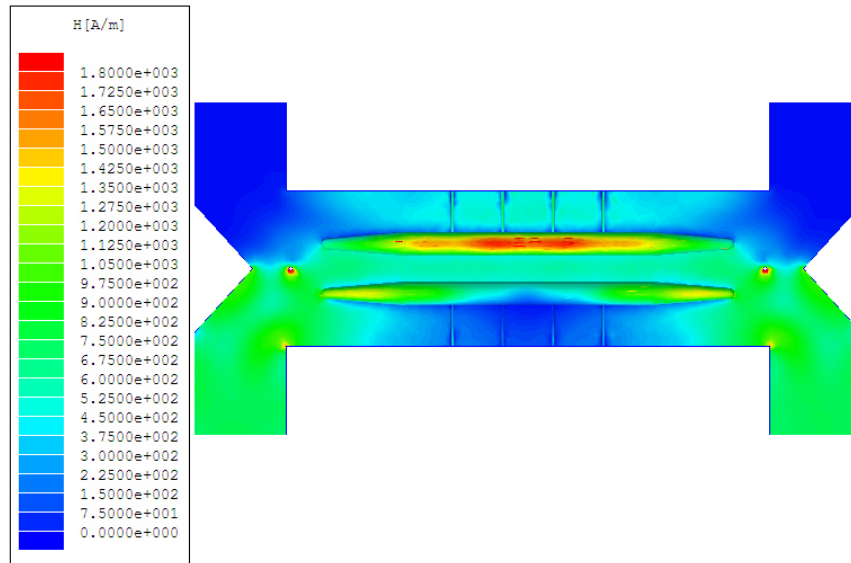
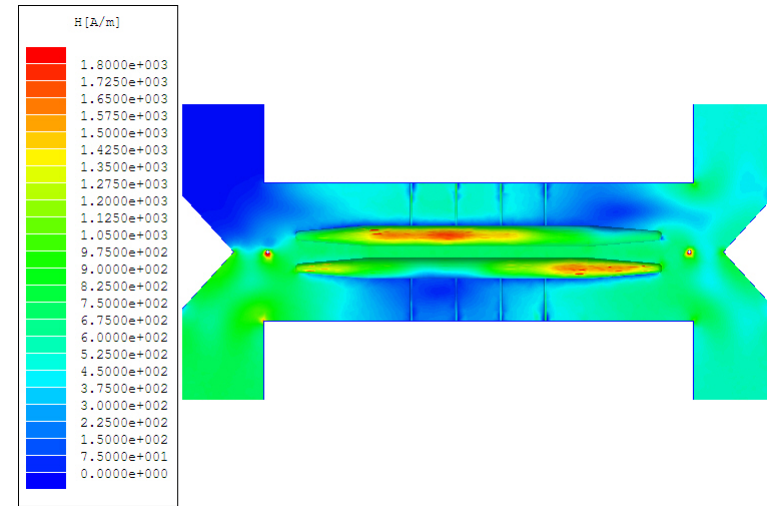
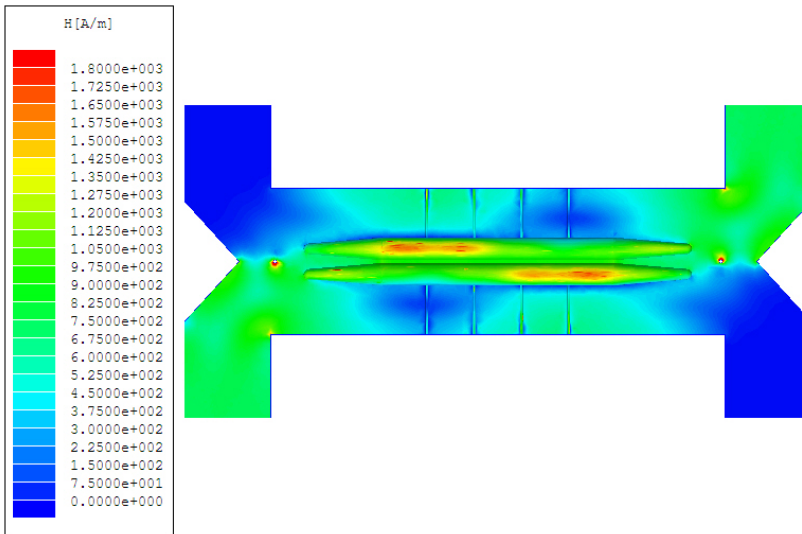


Examples of electric field strength, $P = 1\text{MW}$



Air breakdown limit $\sim 12\text{MW}$

Examples of magnetic field strength, $P = 1\text{ MW}$



Wall loss (copper) = 0.26%

WR650, copper, 1m = 0.12%

Parameters:

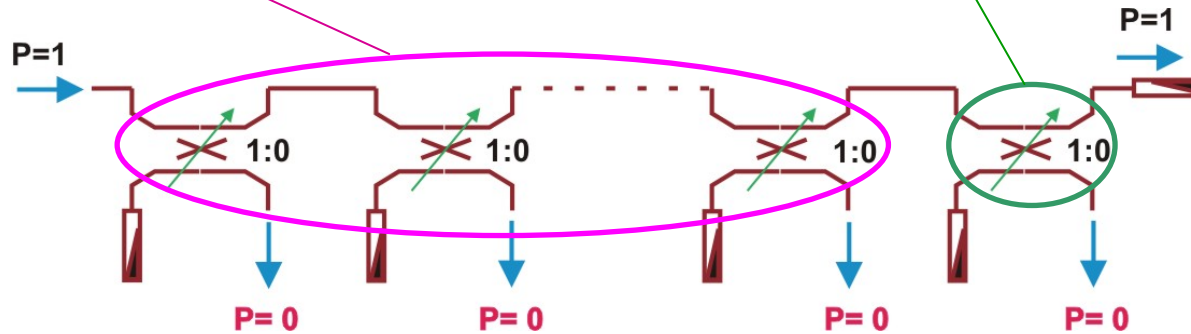
Tuning range - full

Air breakdown limit 12 MW

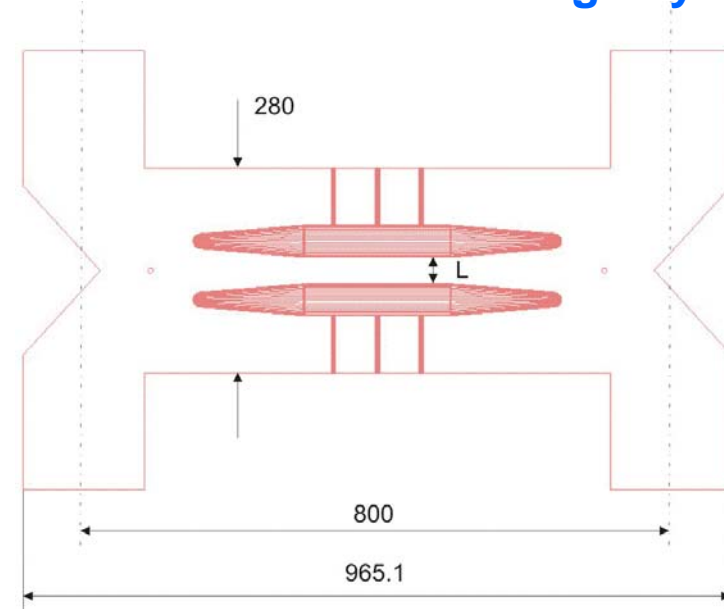
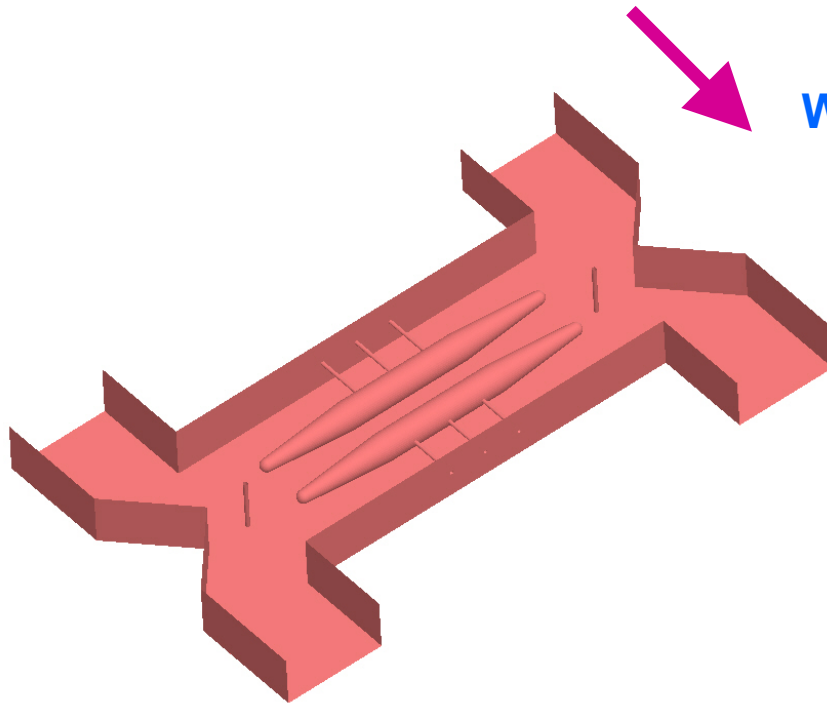
Loss (copper) - 0.26 %

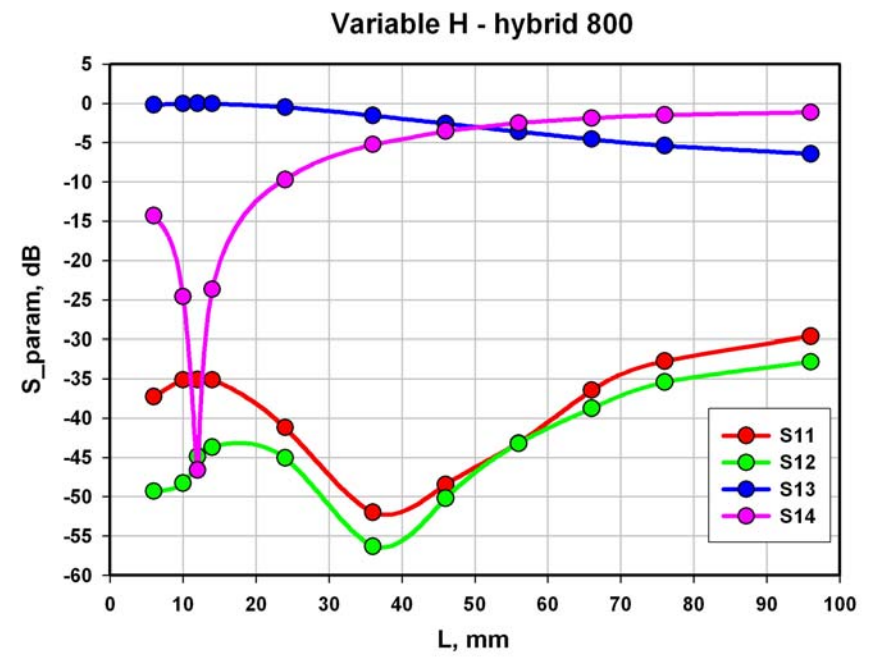
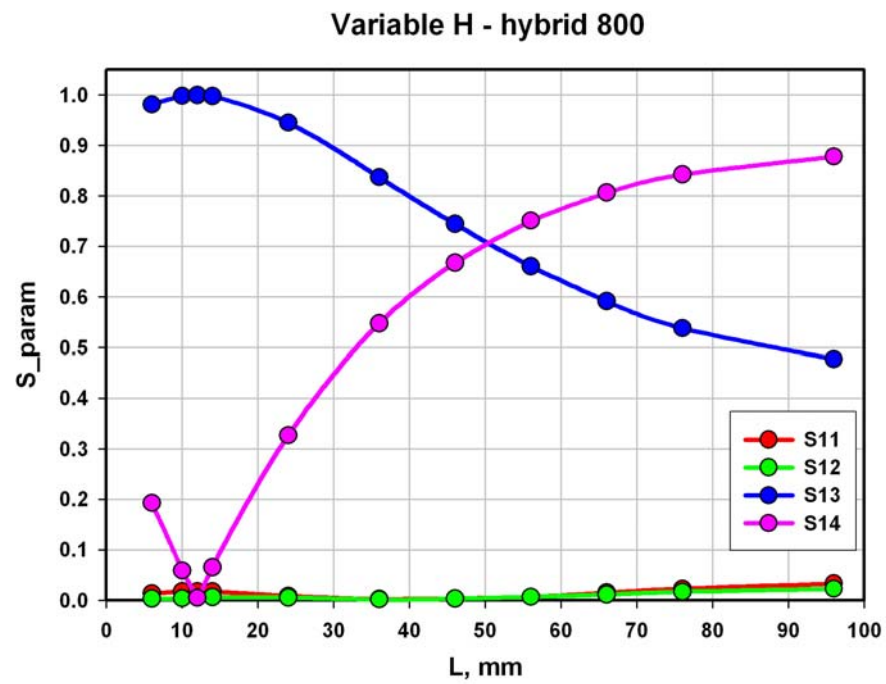
Not have to be full range hybrids

Have to be full range

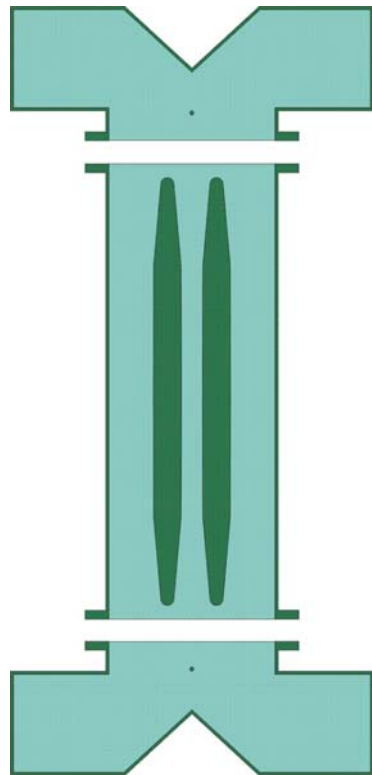


We can use shorter not full range hybrid

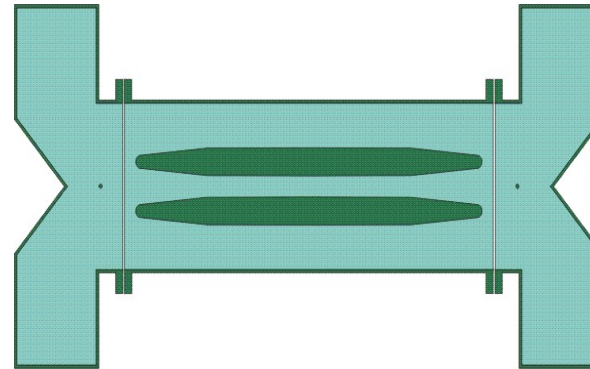




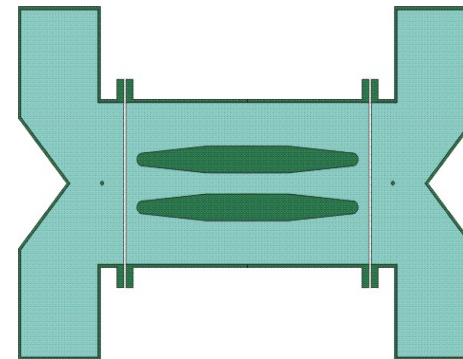
Hybrid can have
module structure:



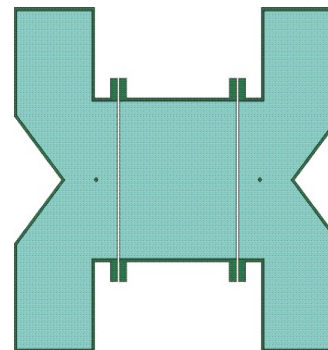
It gives us
flexibility



Hybrid with
full range



Shorter hybrid



Hybrid with fixed
splitting ratio

Conclusion:

- New tape of all metal phase shifter was designed, built and tested.
Phase shift range – **130°**, air breakdown limit ~ **5.5 MW**
Phase shifter was tested till **2.9 MW** without breakdowns.
- New design of more powerful phase shifter is made.
Air breakdown limit ~ **12 MW**
- Design of **full range** variable H-hybrid is made.
Air breakdown limit ~ **12 MW**