Extractors for super-pipe

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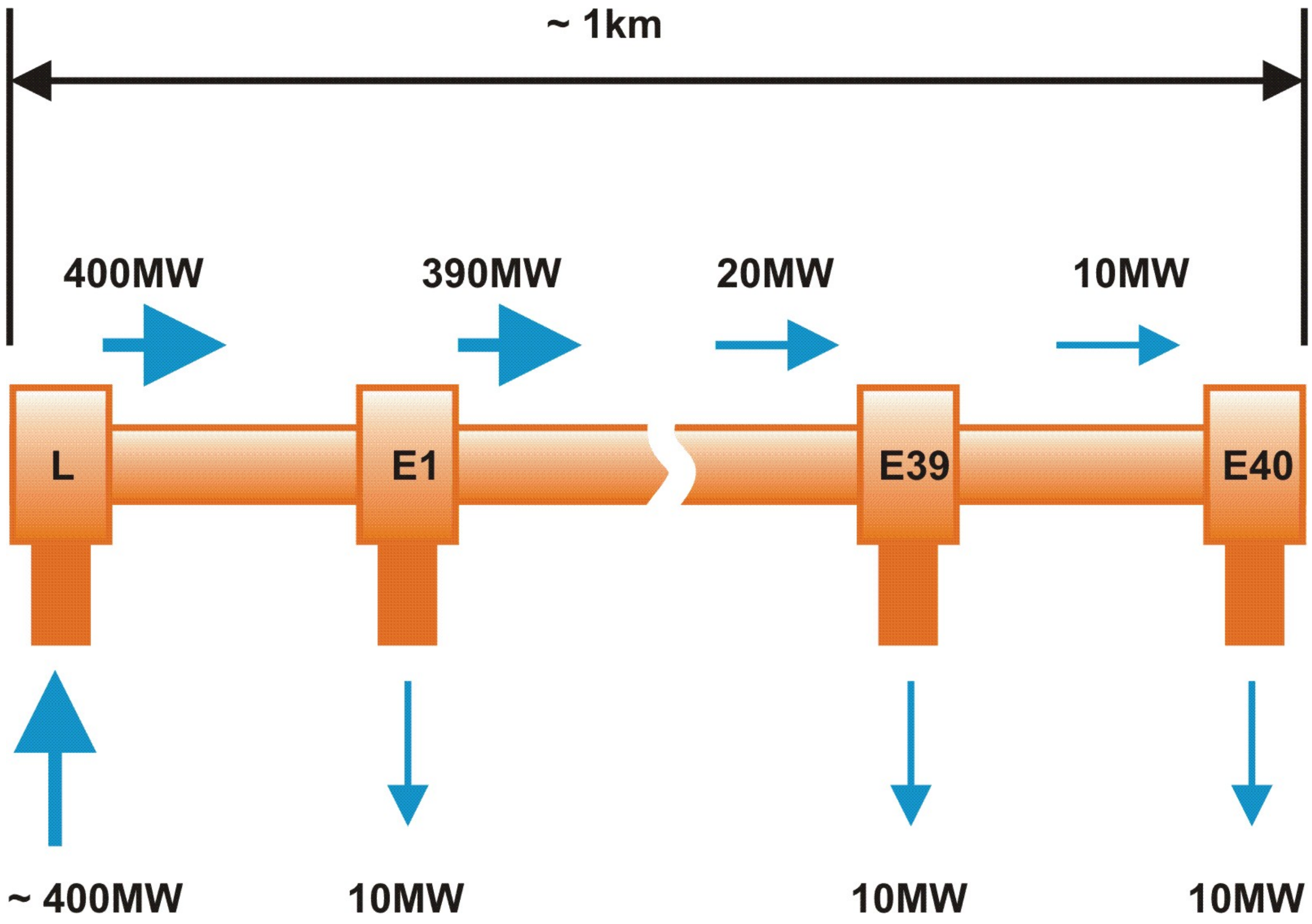
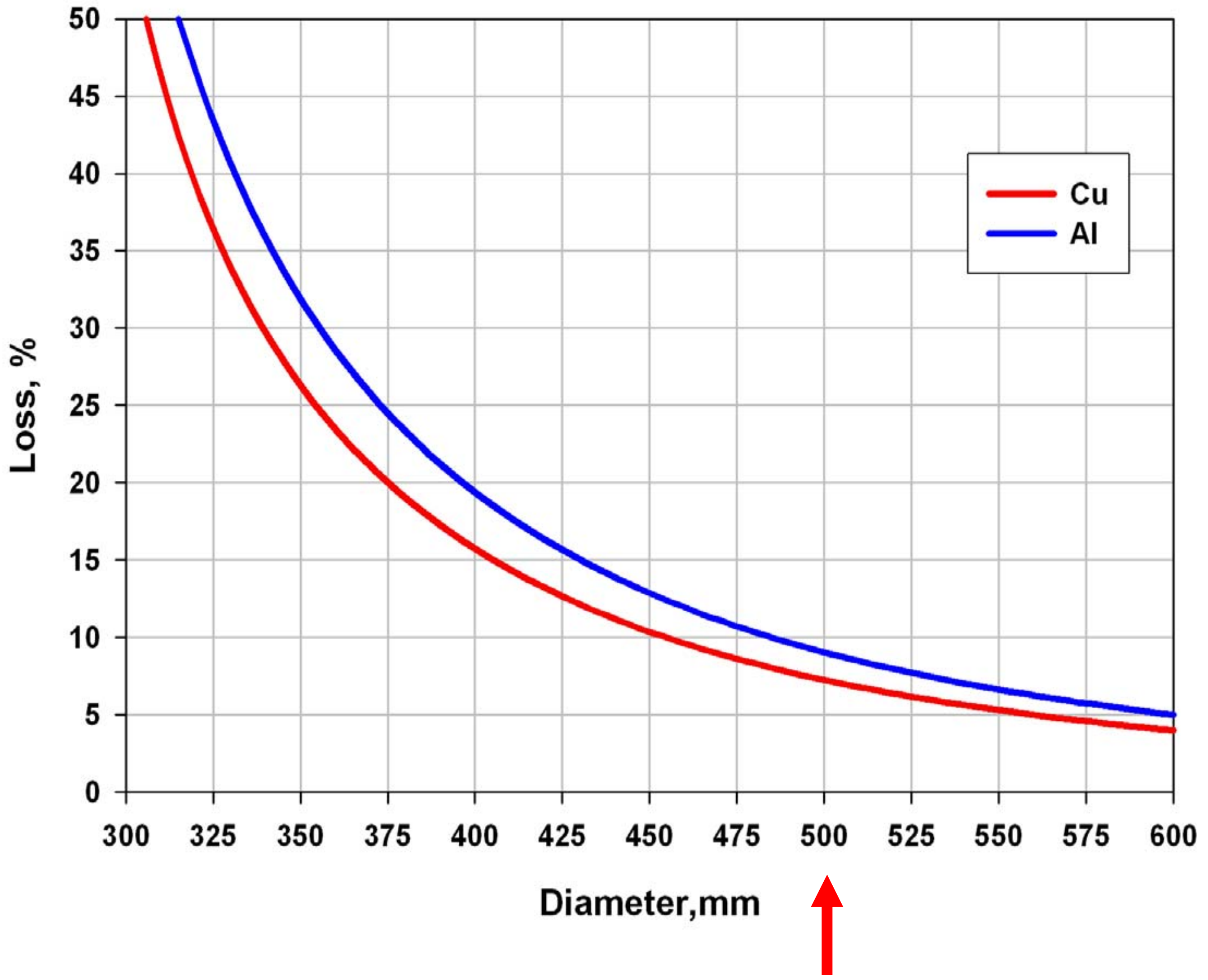
LCWS08, Chicago

November, 2008

Super-pipe scheme

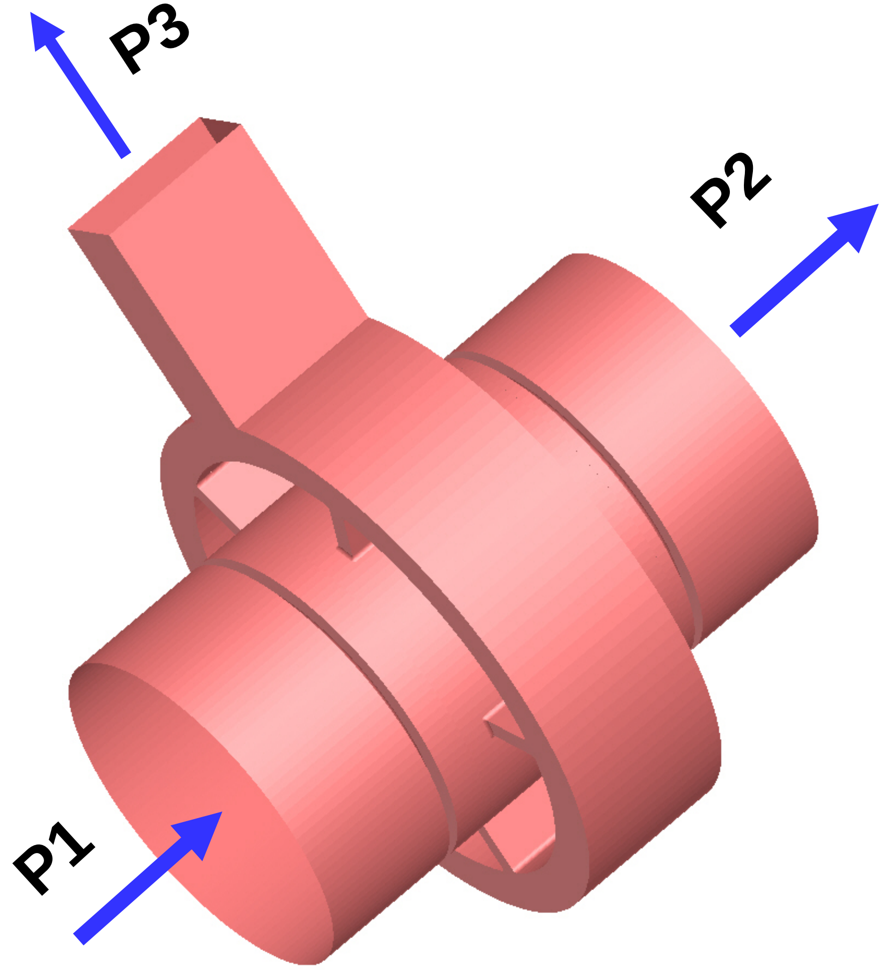


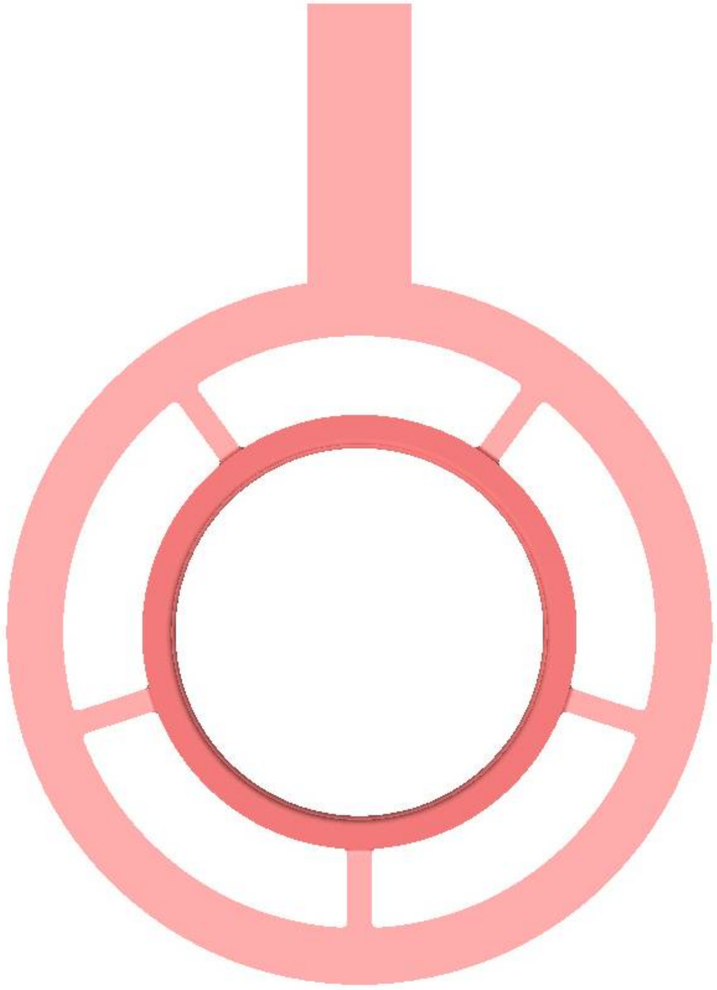
Loss of TE01 mode in 1km circular waveguide.

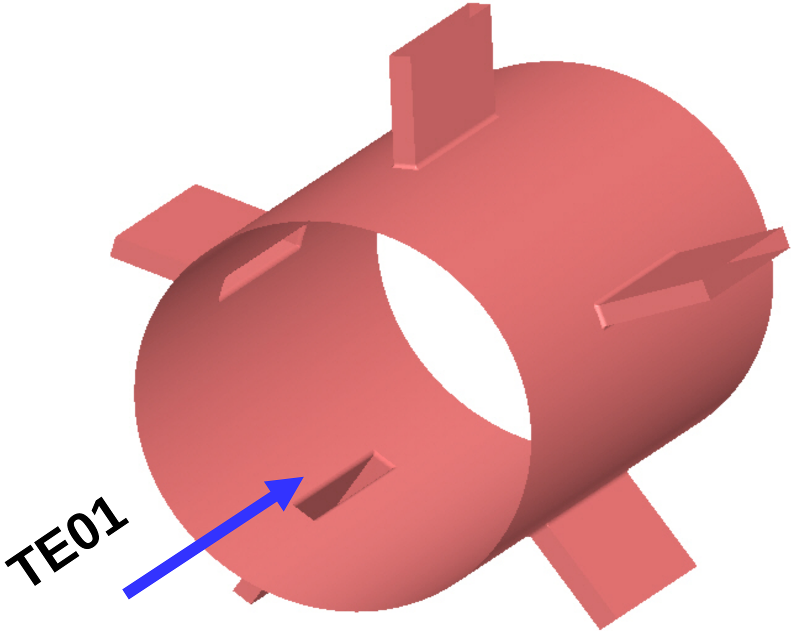


D has to be ~ 500mm

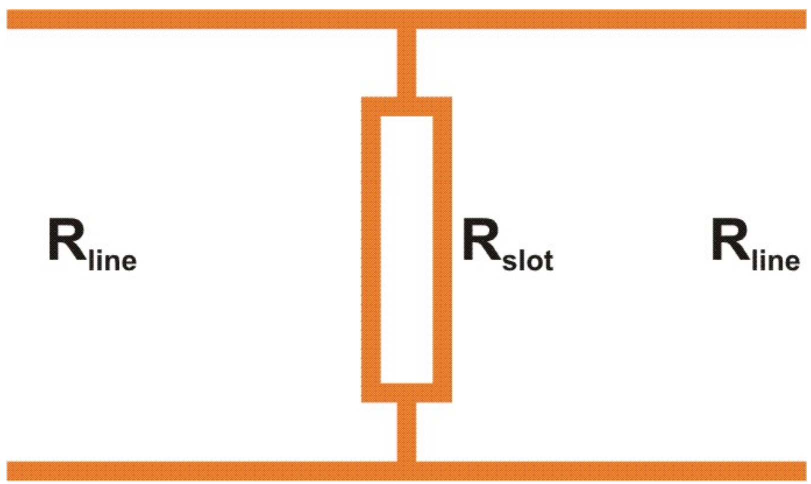
Possible geometry of extractor



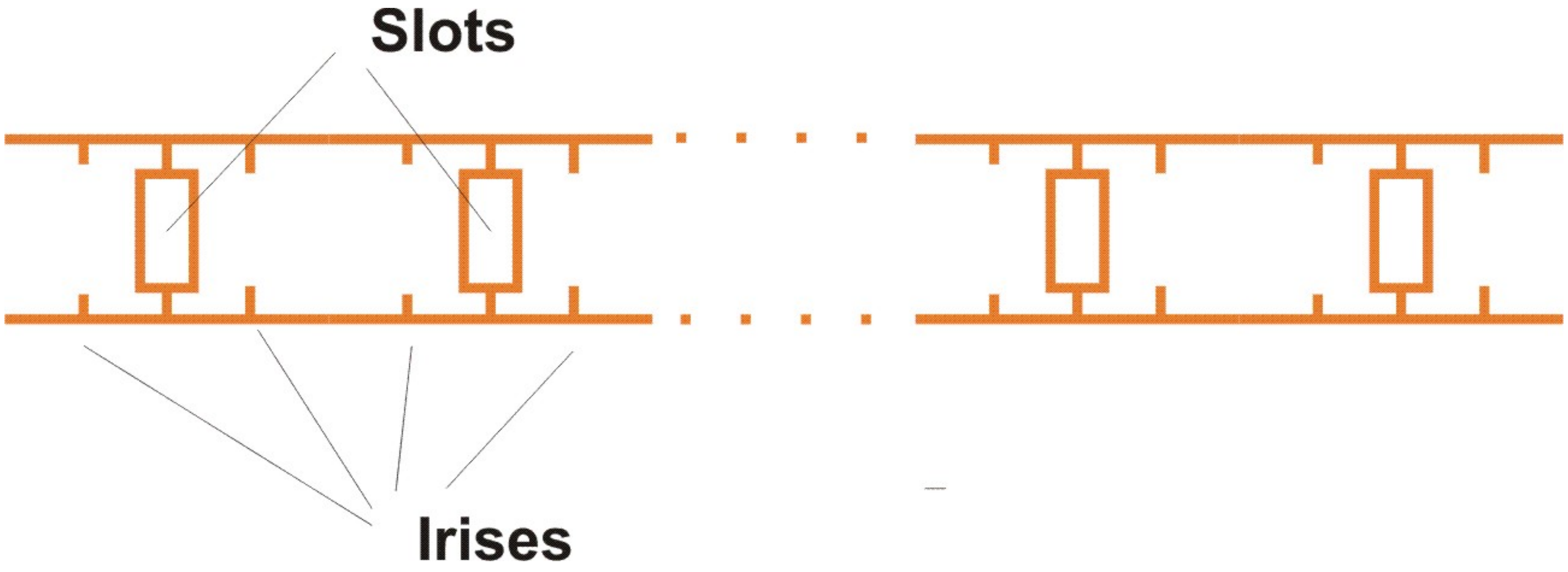




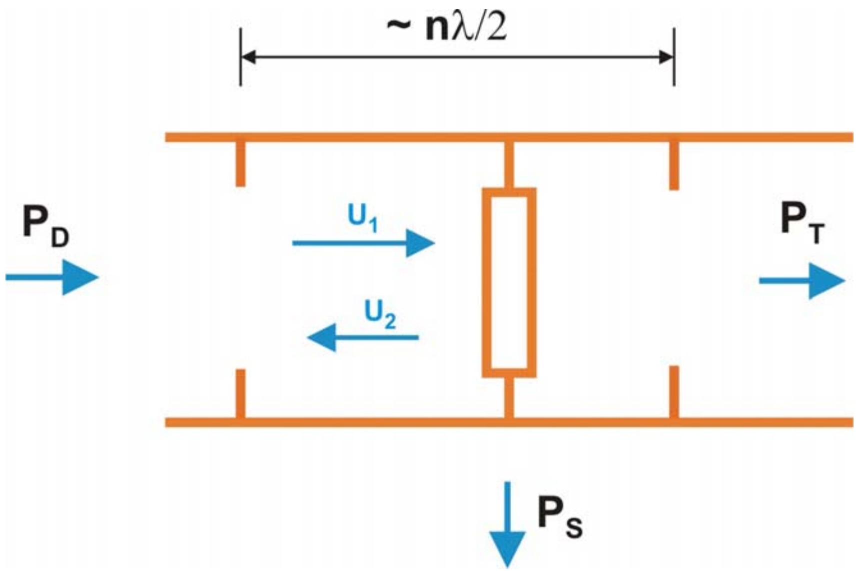
Slots in circular waveguide are described quite accurately by real resistance in the line:



Scheme of pipe



To decrease the cost the slots can be divided into several groups. All slots are equal (same geometry) inside the group. If we divide into only one group, we have all slots are the same. If we divide slots into two groups, we have two types of slots, three groups – three types of slots, etc.



Let's consider equivalent circuit of slot between two iris. It is more or less obvious that optimum position of R (slot) in the maximum or minimum of standing wave in cavity between iris.

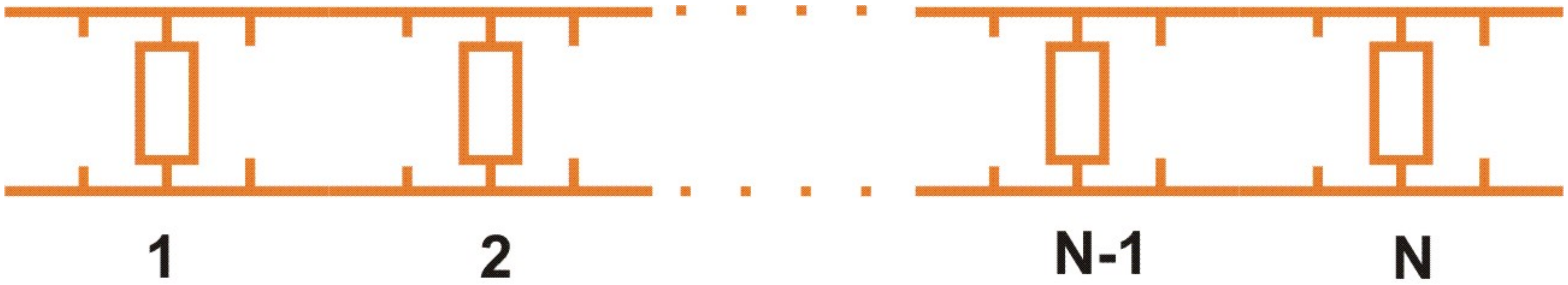
$$P_D \sim \frac{|U_1|^2 - |U_2|^2}{\rho} \qquad P_S \sim \frac{|U_1 + U_2|^2}{R} \qquad \frac{P_S}{P_D} = \alpha = \frac{|(1+G)(1+G)|}{(1+|G|)(1-|G|)} \frac{\rho}{R}$$

$$0 < G < 1 \qquad \alpha = \frac{1+|G|}{1-|G|} \frac{\rho}{R} \qquad |G| = \frac{R\alpha - \rho}{R\alpha + \rho}$$

$$-1 < G < 0 \qquad \alpha = \frac{1-|G|}{1+|G|} \frac{\rho}{R} \qquad |G| = -\frac{R\alpha - \rho}{R\alpha + \rho}$$

Ratio of storage energy to direct power is proportional to:

$$\frac{W}{P_D} \sim \frac{1+|G|^2}{1-|G|^2} = \frac{1+\frac{(R\alpha-\rho)^2}{(R\alpha+\rho)^2}}{1-\frac{(R\alpha-\rho)^2}{(R\alpha+\rho)^2}} = \frac{(R\alpha)^2+\rho^2}{2R\alpha\rho} \sim \frac{R\alpha}{\rho}+\frac{\rho}{R\alpha} = \gamma$$



$$\alpha_i = \frac{1}{N+1-i} \qquad \gamma_i = R_i\alpha_i + \frac{1}{R_i\alpha_i} \qquad \rho = 1$$ - **Impedance of line**

$$P_{Di} = \frac{N+1-i}{N}$$ - **Direct power to i - element**

To minimize storage energy we should minimize (find optimal R_i):

$$W = \sum_{i=1}^{N} P_{Di}\gamma_i = \sum_{i=1}^{N}\left(\frac{N+1-i}{N}\right)\left(R_i\alpha_i + \frac{1}{R_i\alpha_i}\right)$$

To decrease cost the extractors can be divided to several groups. Inside the groups all extractors have the same geometry of slots and surrounding waveguides (the same R_i)

One group:

$R_1 = R_2 = \ldots. R_{40}$

Two groups:

$R_1 = R_2 = \ldots. R_{20}$

$R_{21} = R_{22} = \ldots. R_{40}$

Three groups:

$R_1 = R_2 = \ldots. R_{13}$

$R_{14} = R_{15} = \ldots. R_{26}$

$R_{15} = R_{16} = \ldots. R_{40}$

Four groups:

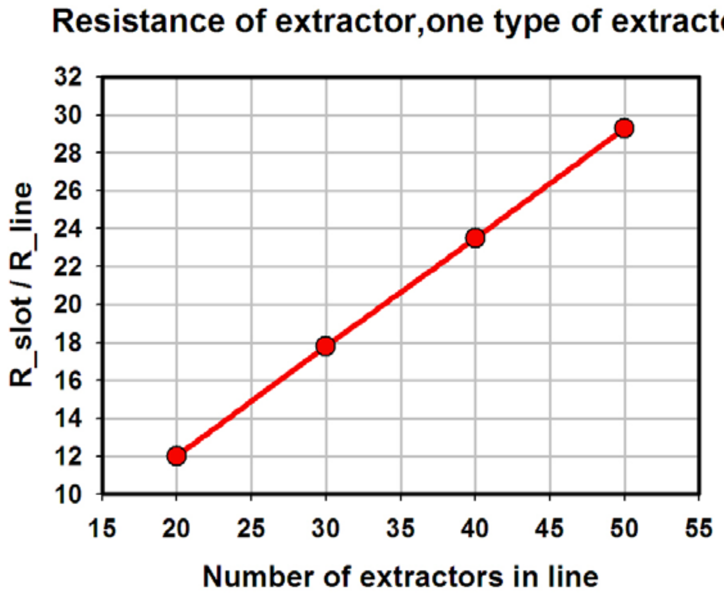
$R_1 = R_2 = \ldots. R_{10}$

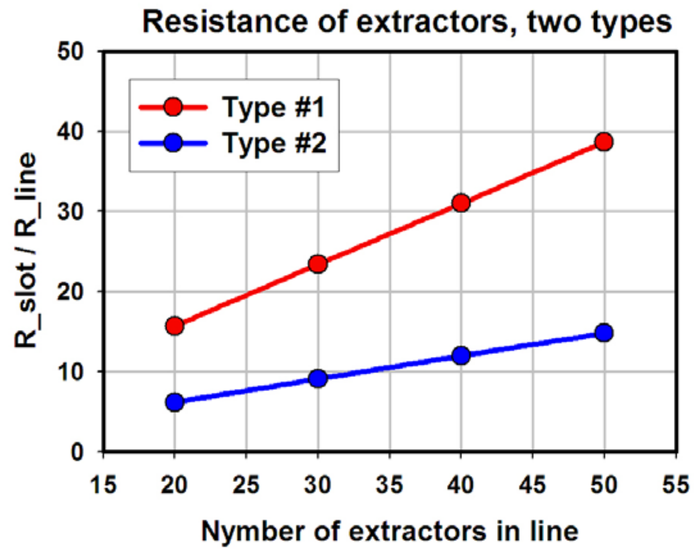
$R_{11} = R_{12} = \ldots. R_{20}$

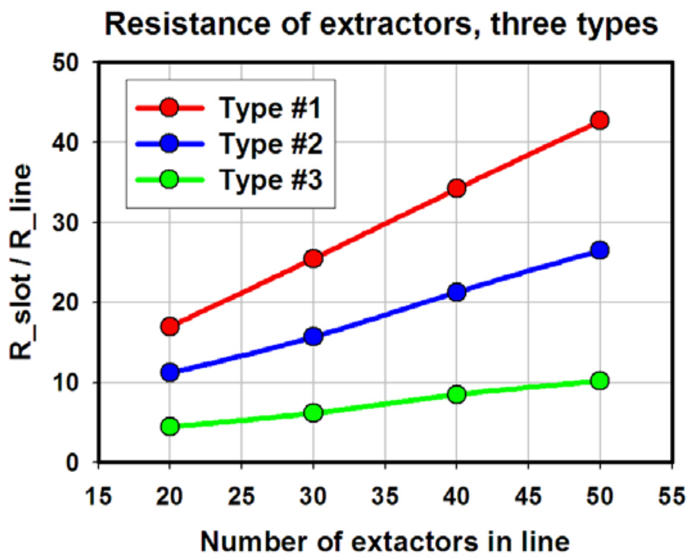
$R_{21} = R_{22} = \ldots. R_{30}$

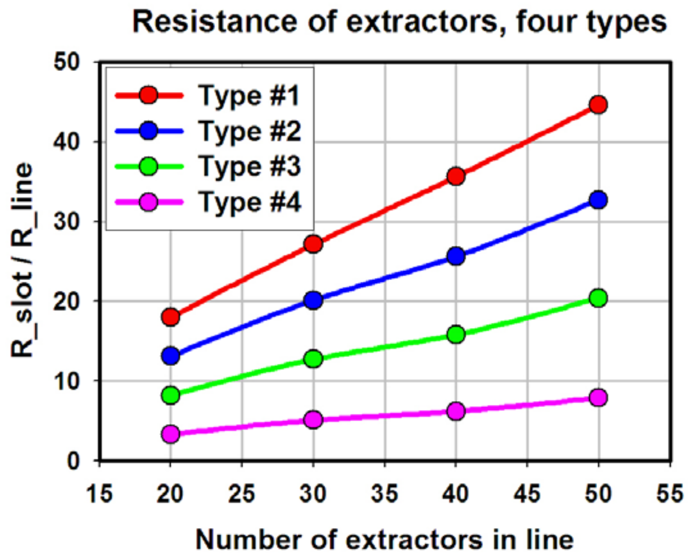
$R_{31} = R_{32} = \ldots. R_{40}$

We can optimize the ratio R_{slots}/R_{line} to minimize storage energy (and loss) in extractors:









Optimal R/ρ for N_{ext} = 40

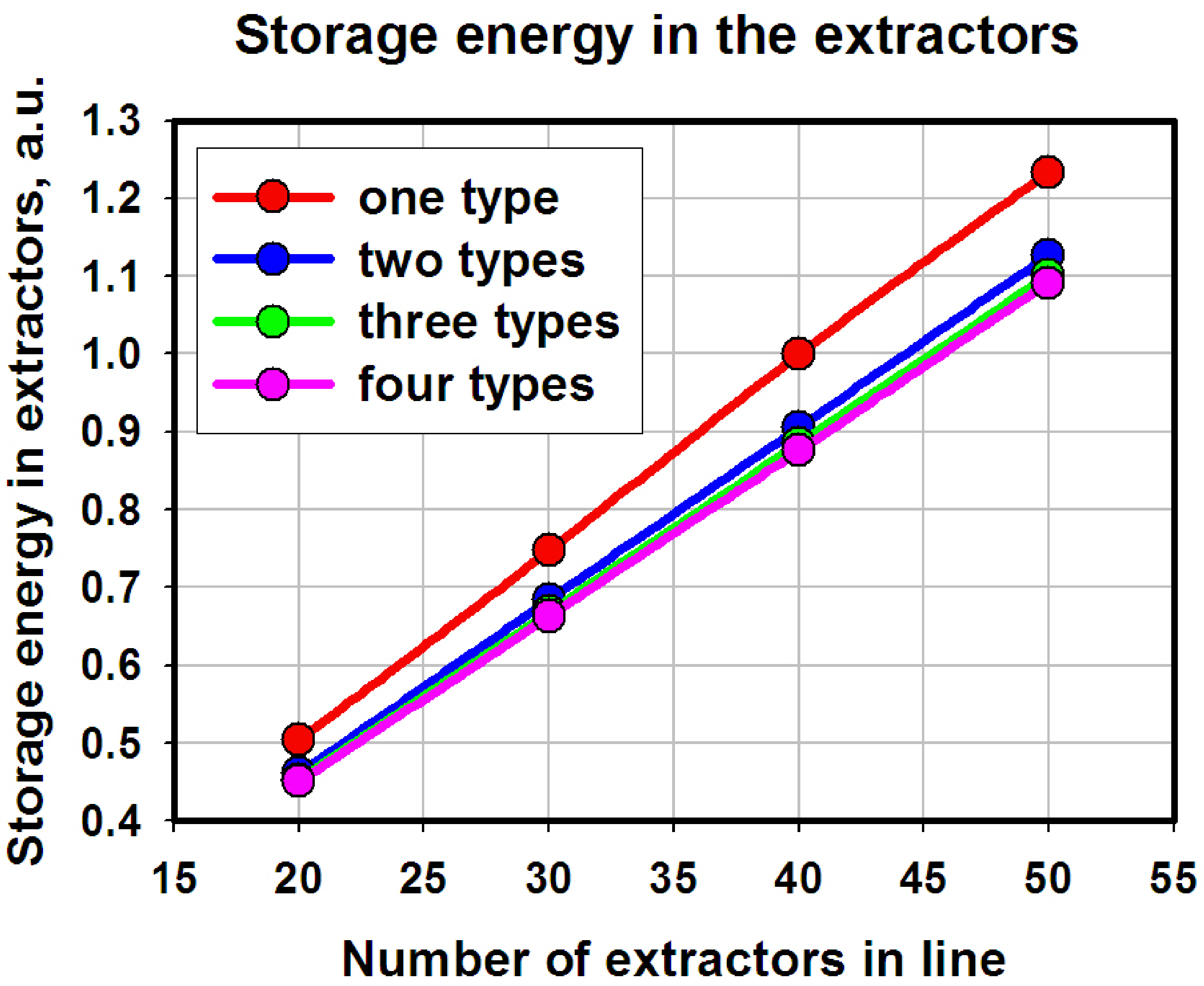
One group:
R/ρ $= 23.5$

Two group:
$R_1/\rho = 31$
$R_2/\rho = 12$

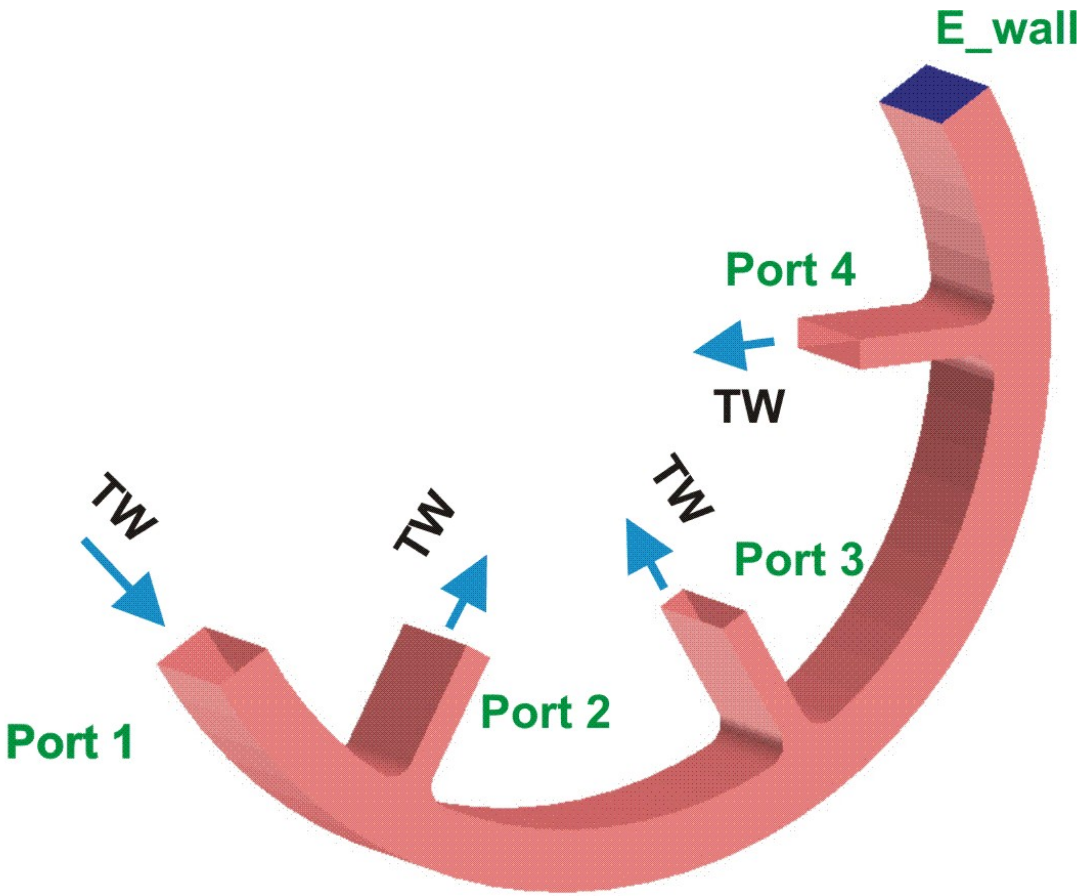
Three group:
R1/ρ $= 34.2$
R2/ρ $= 21.3$
R3/ρ = 8.5

Four group:
R1/r = 35.6
R2/r = 25.6
R3/r = 15.8
R4/r = 6.2

Storage energy for different number of extractor groups



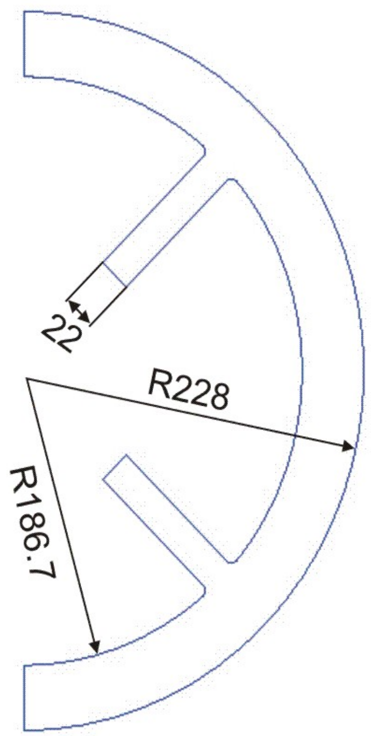
Approach to design of surrounding waveguide



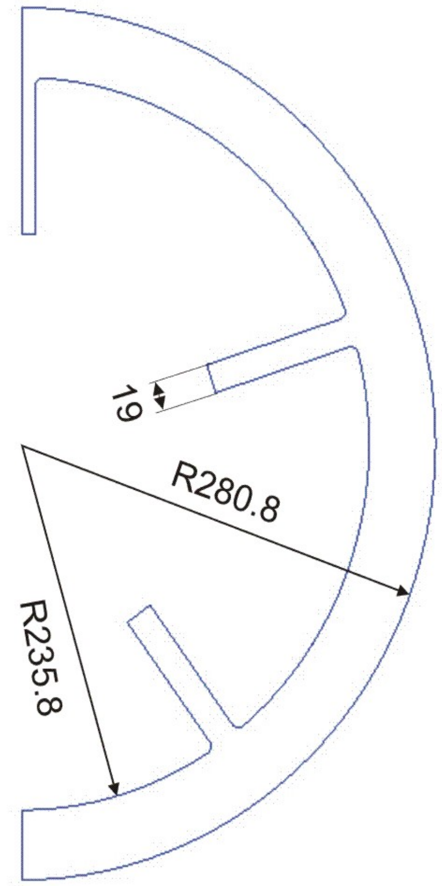
A2 = A3 = … An

φ2 = φ3 = … φ**n**

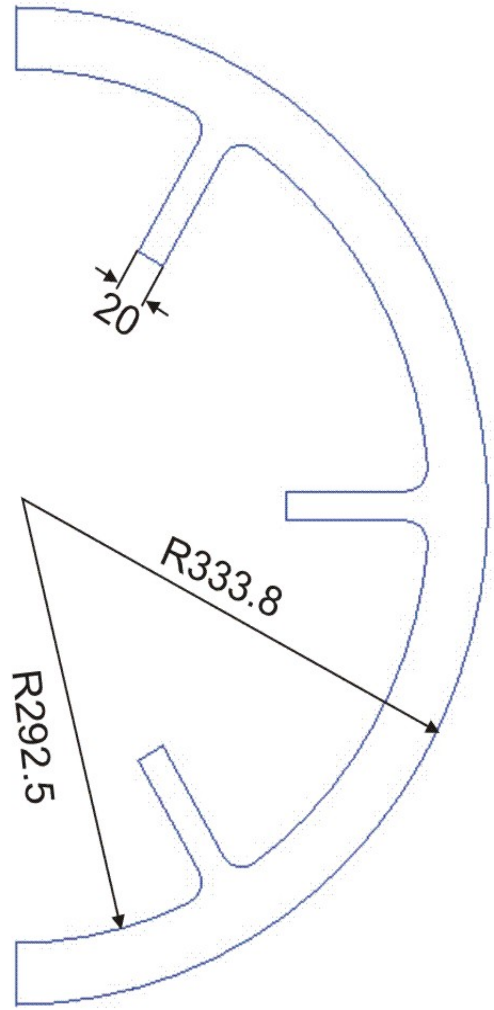
Surrounding waveguides



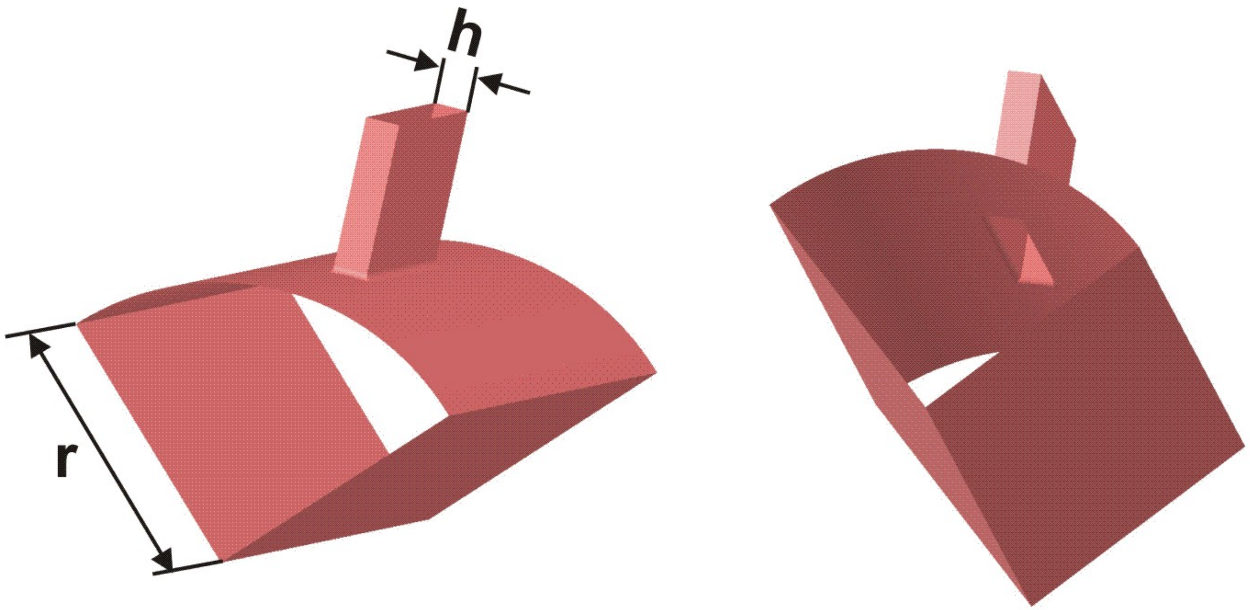
4 slots



5 slots



6 slots (not exact solution, S11 ~0.25)



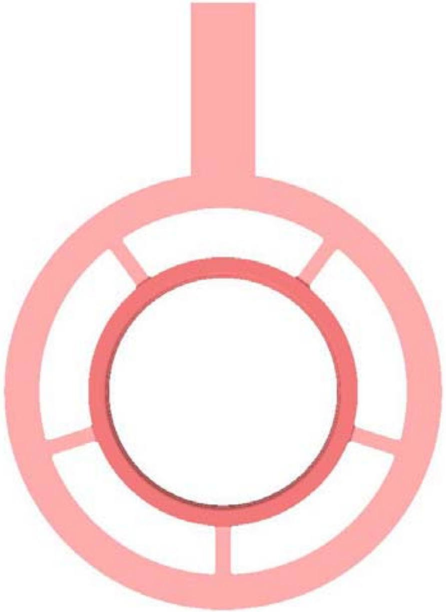
Surrounding waveguide connected with circular waveguide through slots (waveguides). R_{slot}/ρ depends on r and h. But h is fixed (condition of TW in surrounding waveguide). We have only one parameter r. But r is limited by radius of surrounding waveguide. For 4 slot geometry we can get maximum Rslot /r is about 10. But we need Rslot /r ~ 35. We have to choose geometry with 5 or more slots.

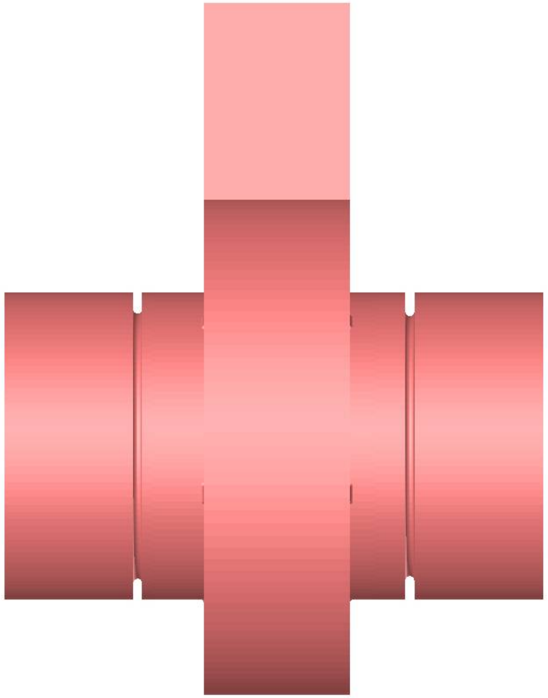
5 – slot surrounding waveguide was chosen

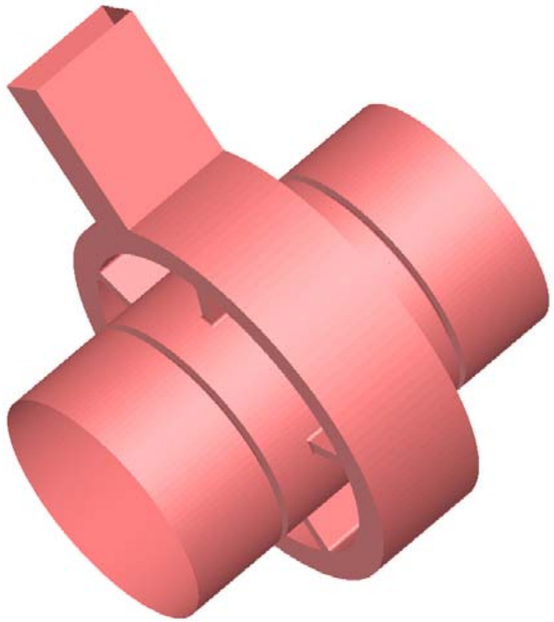
Extractors were divided into 4 groups:

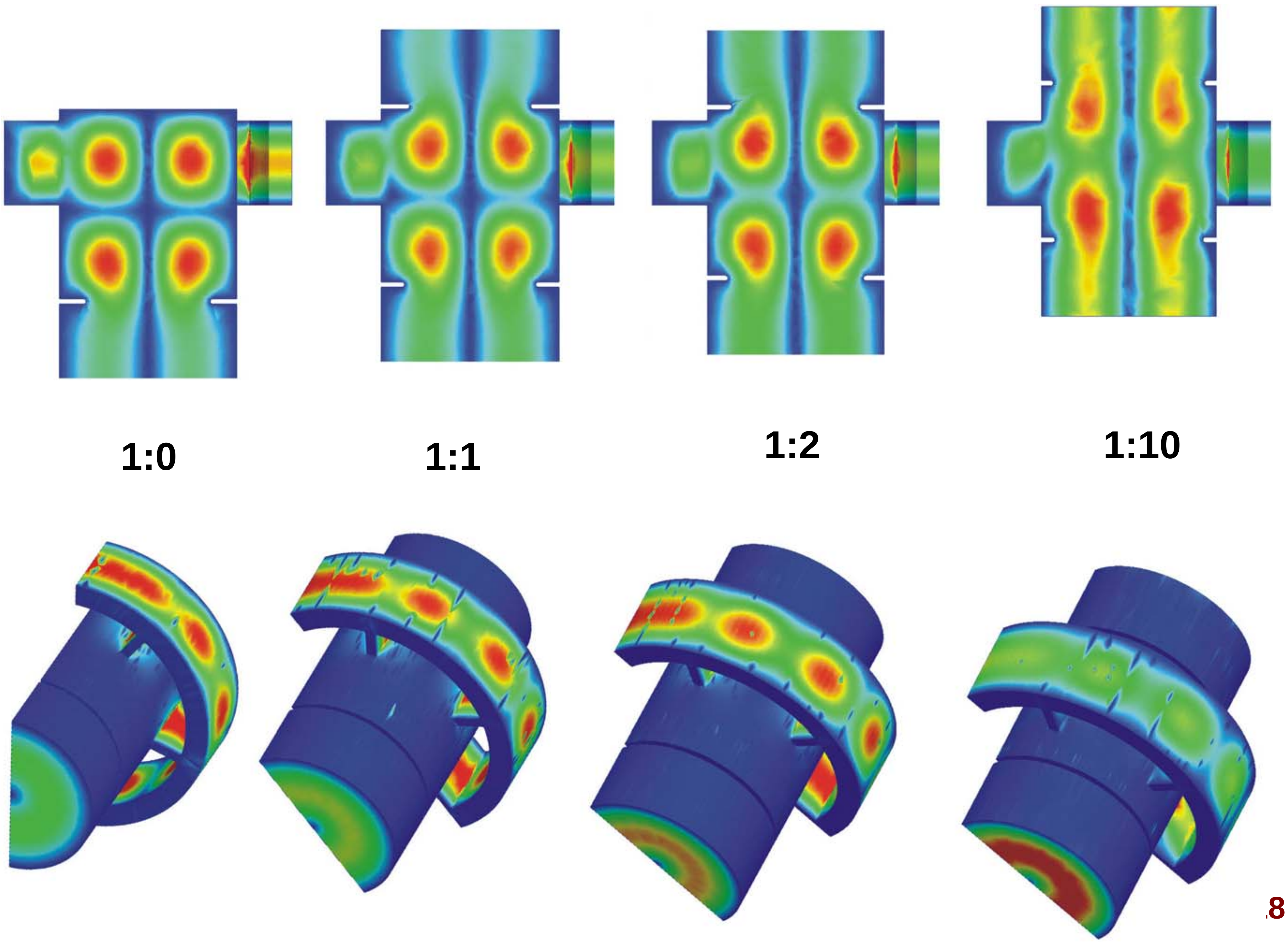
1:0 -1:10	tap-off ratio
1:11 – 1:20	tap-off ratio
1:21 – 1:30	tap-off ratio
1:31 – 1:40	tap-off ratio

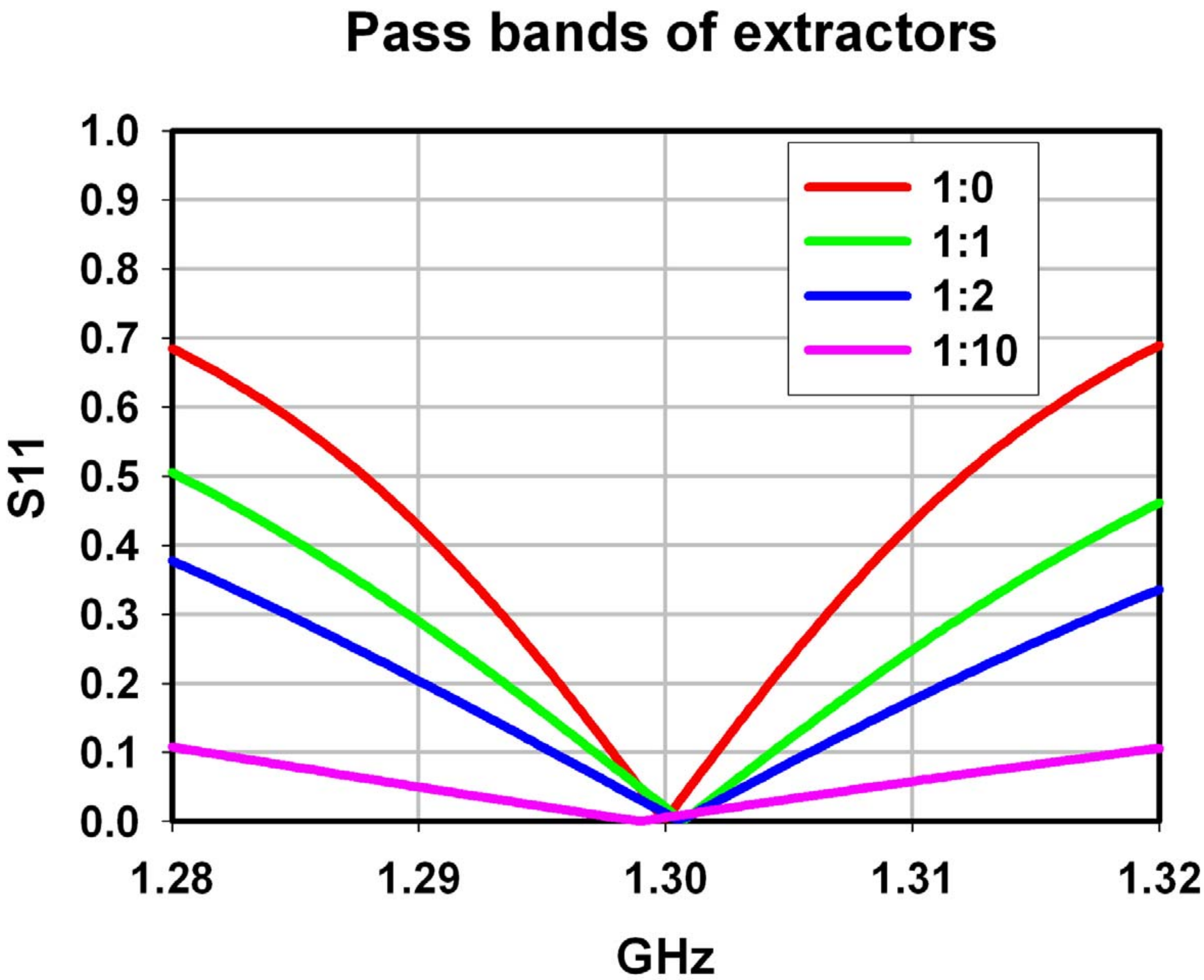
Extractor 1:10

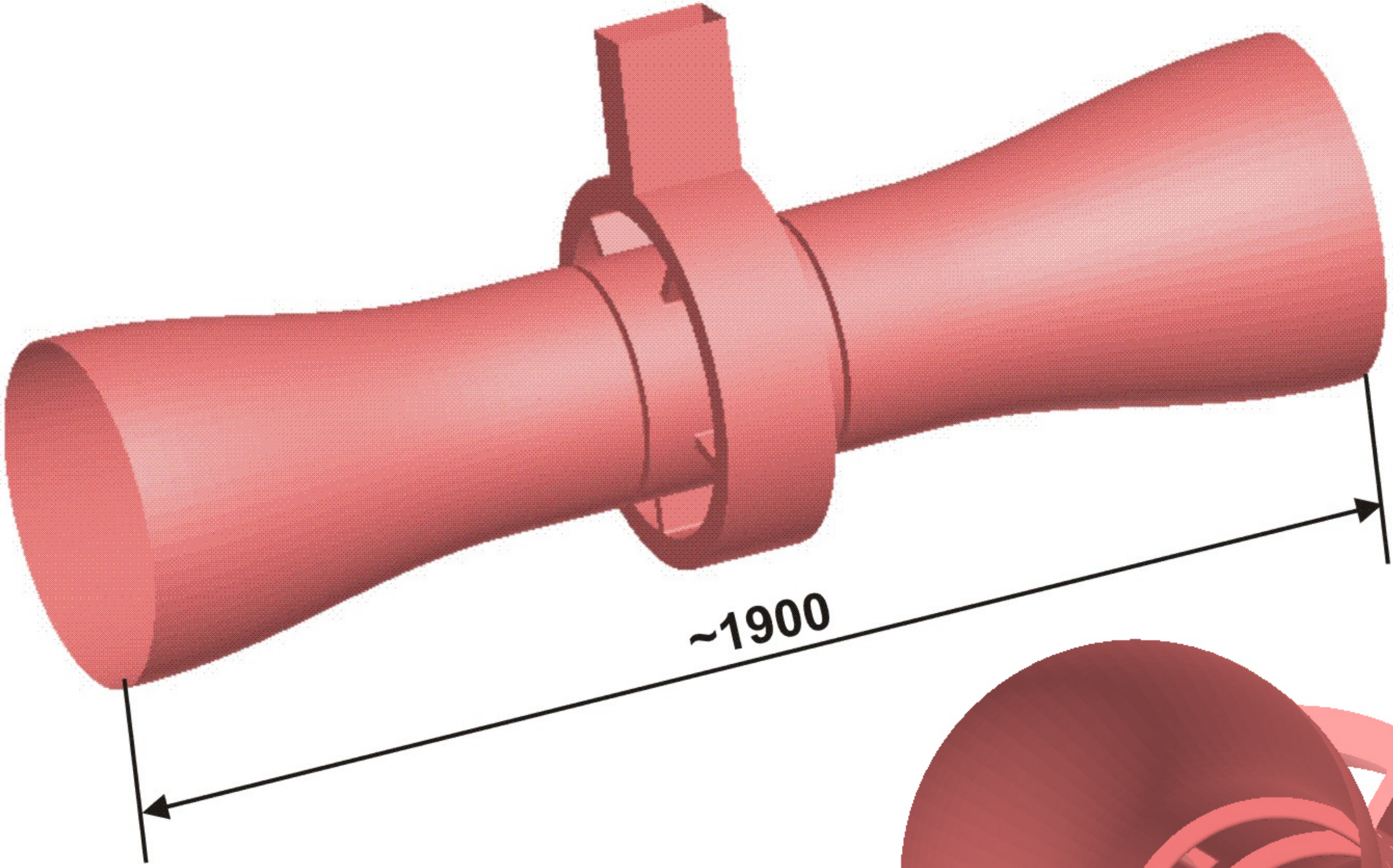


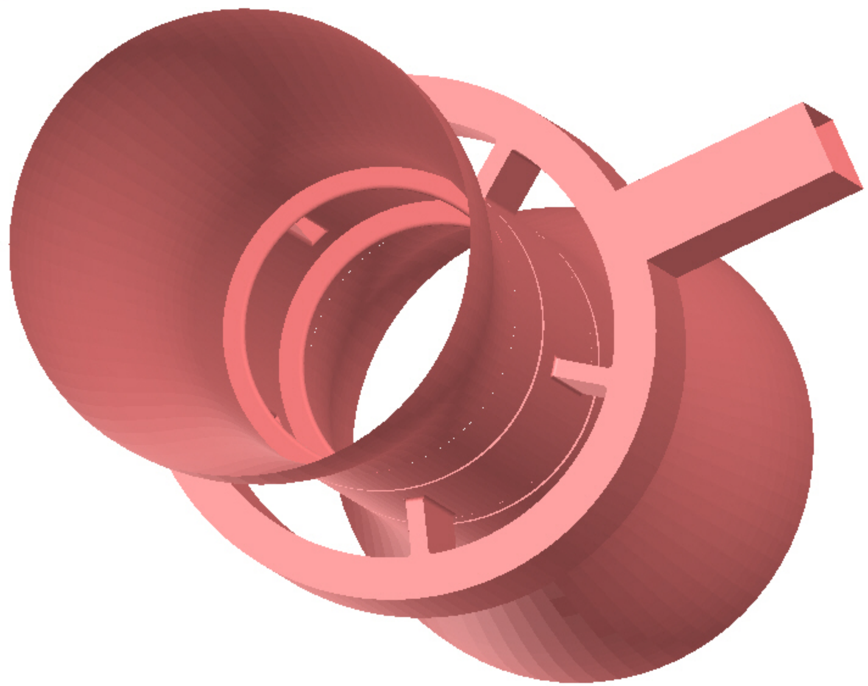





1:0
1:1
1:2
1:10


Pass bands of extractors
S11
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
1:0
1:1
1:2
1:10
1.28
1.29
1.30
1.31
1.32
GHz


~1900



Conclusion:

1. It seems that big number of extractors with different extraction ratio can be made using only few identical wrap around geometries.

2. Tasks for the nearest futures are to find optimal number of groups and optimal geometries.