13th Joint workshop on Electron Cyclotron Emission and Electron Cyclotron Resonance Heating

Characteristics of optimized diplexers based on the spatial and angular Talbot effects

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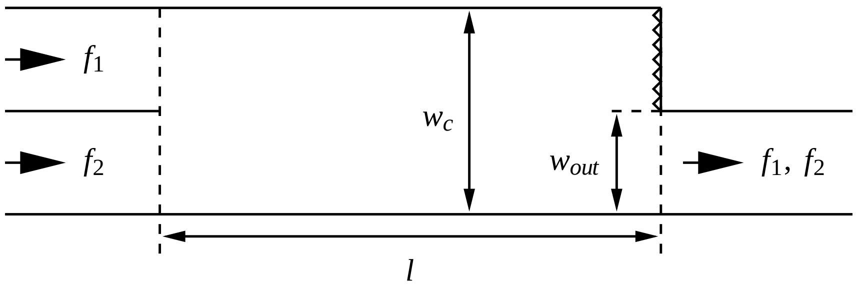
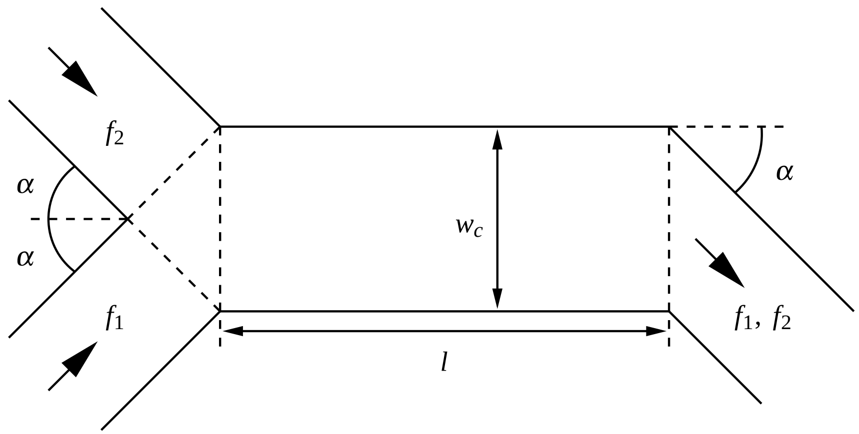
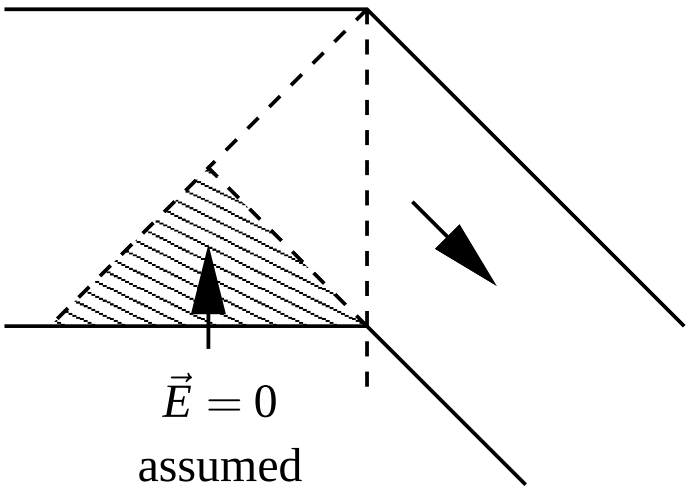
Principle

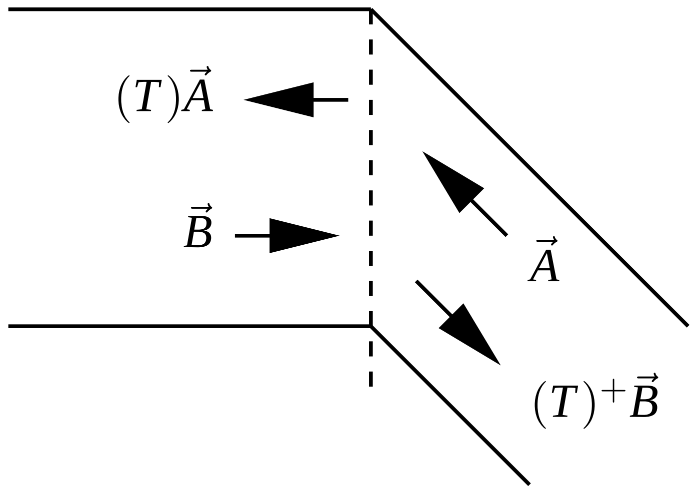
- The diplexer consists of an oversized rectangular waveguide.
- The TE_{10}-waves coming from the inputs excite TE_{m0} mode spectra, which propagate with different phase constants
- One can find dimensions, where the field distributions at the end of the combining section match the field pattern of the TE_{10}-mode of the output waveguide
- The goal is to maximize the TE_{10} output power for both frequencies





- The mode spectra in the main waveguide can be calculated with mode-matching (reflected waves are neglected)
- For the spatial diplexer, the output mode spectrum is calculated the same way as at the input
- For the angular diplexer, the boundary between main- and output waveguide is not perpendicular to the axis of the output waveguide
- Solutions are the construction of a *virtual waveguide wall* or the solution using the *pseudo-inverse* of the transmission matrix for the other direction





Analytical solutions

For highly oversized waveguides $(k_0 \gg \frac{m\pi}{w_c})$, the phase constant β_m of a $\mathrm{TE_{m0}}$-Mode becomes:

$$\beta_m \approx k_0 \left[1 - \frac{1}{2}\left(\frac{m\pi}{w_c k_0}\right)^2\right]$$

At a distance of

$$z = \frac{4nw_c^2}{\lambda}$$

from the input, we get a symmetric field reproduction for even n and an asymmetric field reproduction for odd n.

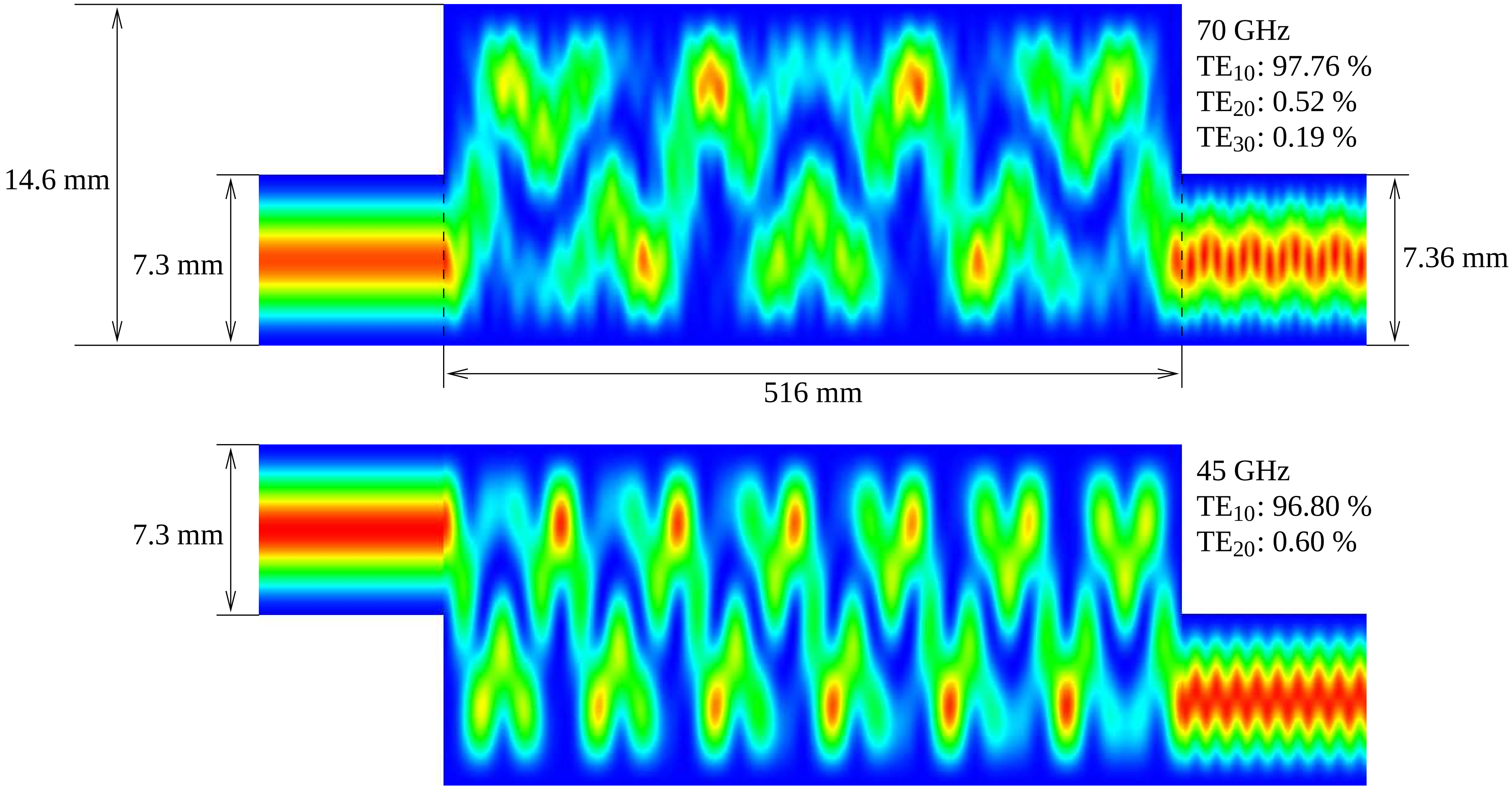
This leads to analytical solutions, e.g. $f_1 : f_2 = 3 : 2$, $l = \frac{8w_c^2}{\lambda_1} = \frac{12w_c^2}{\lambda_2}$

Disadvantages: Arbitrary frequency ratios should be allowed. Analytical solutions are unsuitable large.

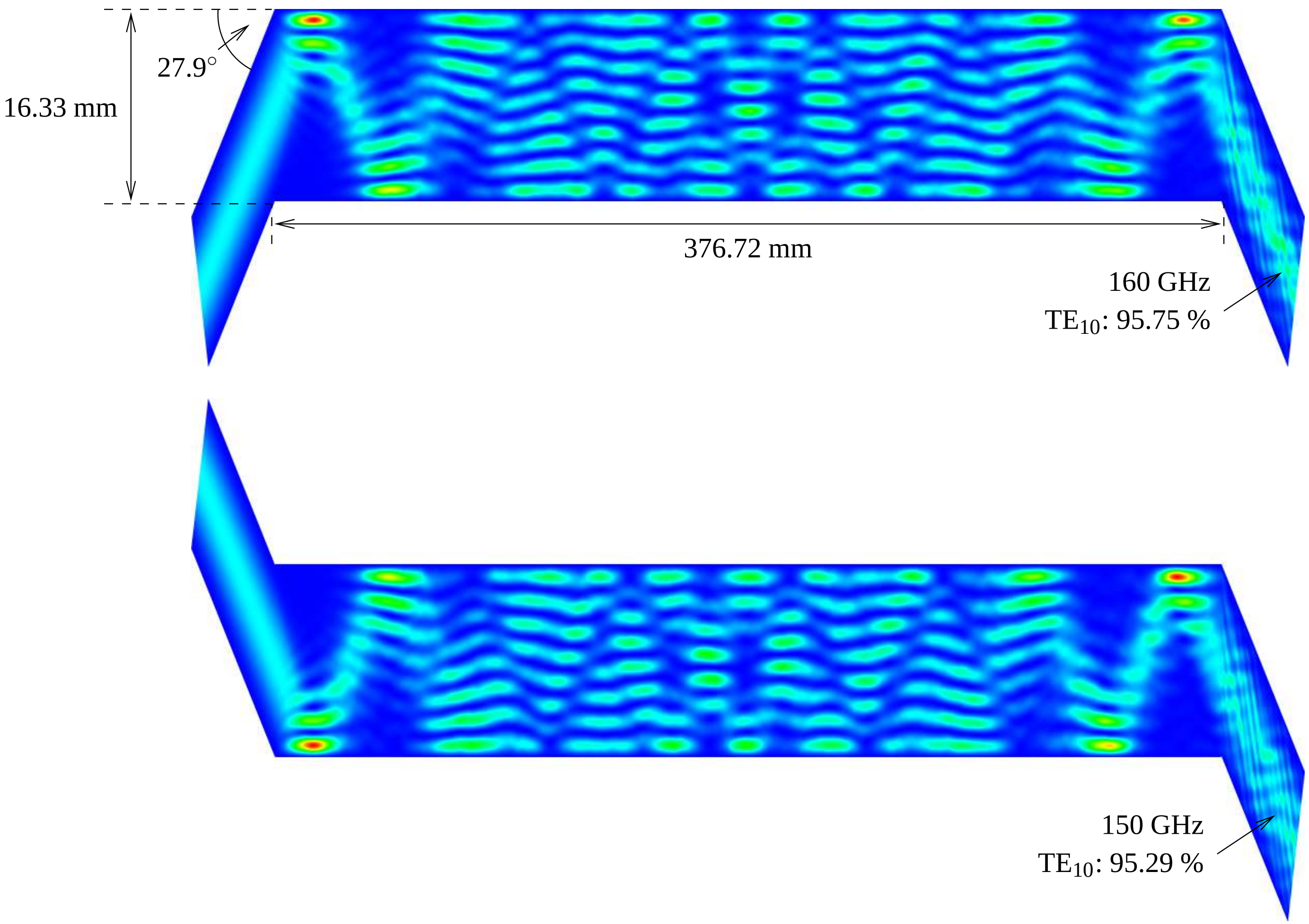
Optimization

- The goal is to maximize the TE_{10}-Output power for both frequencies
- To prevent the algorithm from finding unsuitable long solutions, the length of the waveguide is kept fixed during the optimization.
- Variable parameters for the spatial diplexer are the width w_c of the main waveguide and the width of the output waveguide.
- Variable parameters for the angular diplexer are the width w_c of the main waveguide and the angle α.
- A combined *Simulated Annealing/Downhill Simplex* method from the book *Numerical Recipes in C* is used.

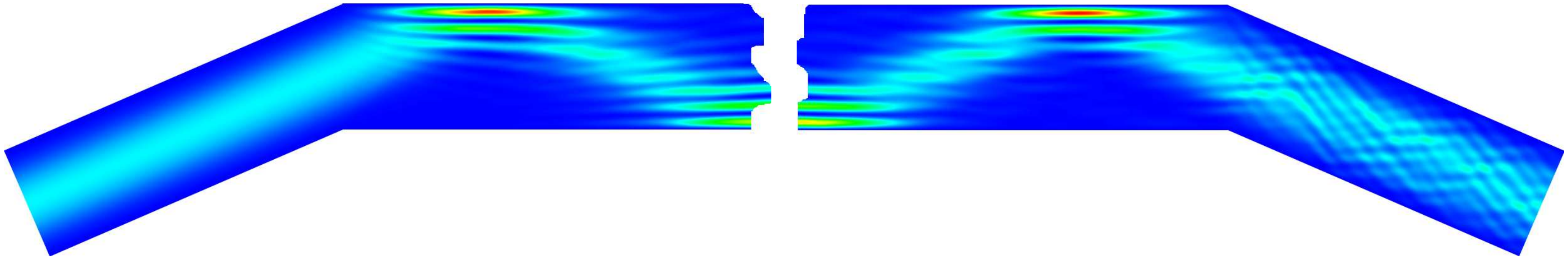
Results: Spatial diplexer



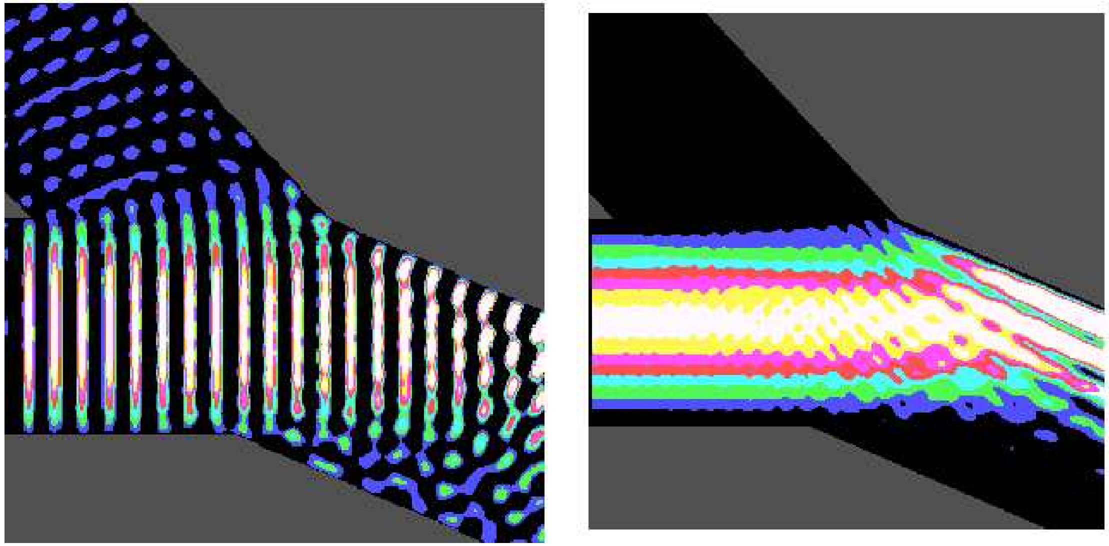
Results: Angular diplexer



Detailed view of input and output ($f = 75$ GHz, $l = 1.09$ m, $w_c = 37.3$ mm, $\alpha = 23.39^\circ$)

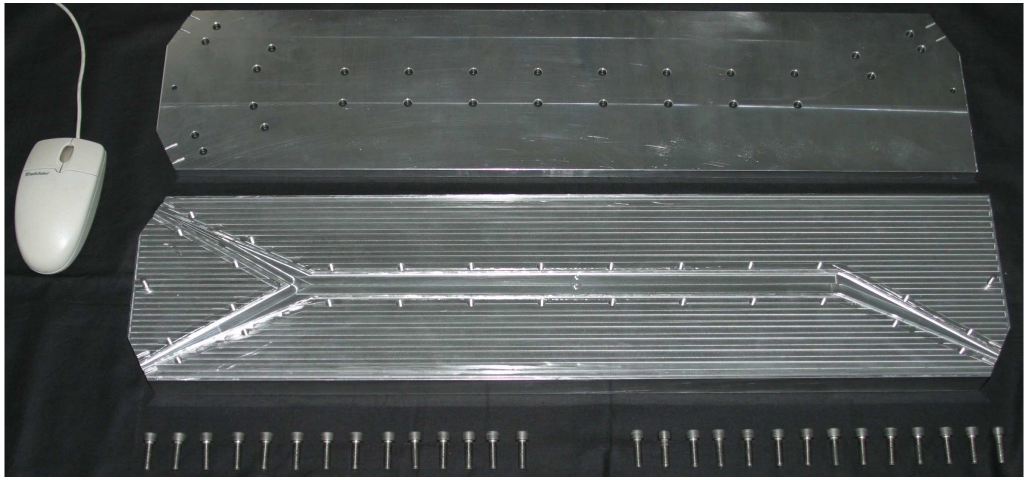


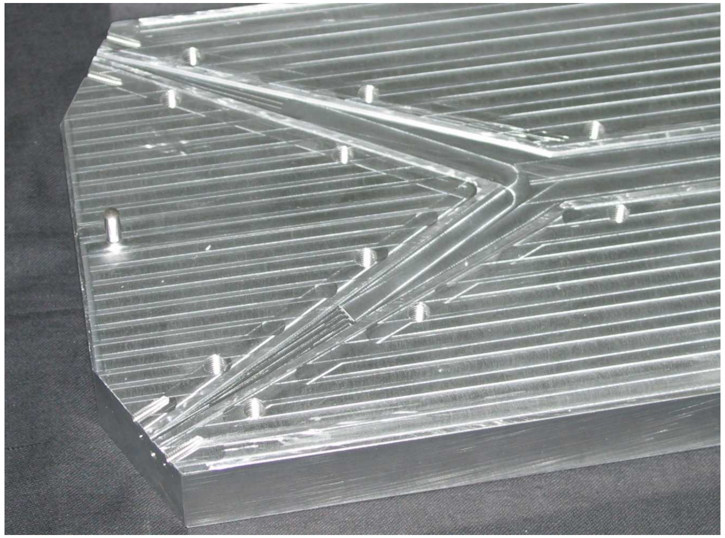
Corresponding Results of a FDTD calculation

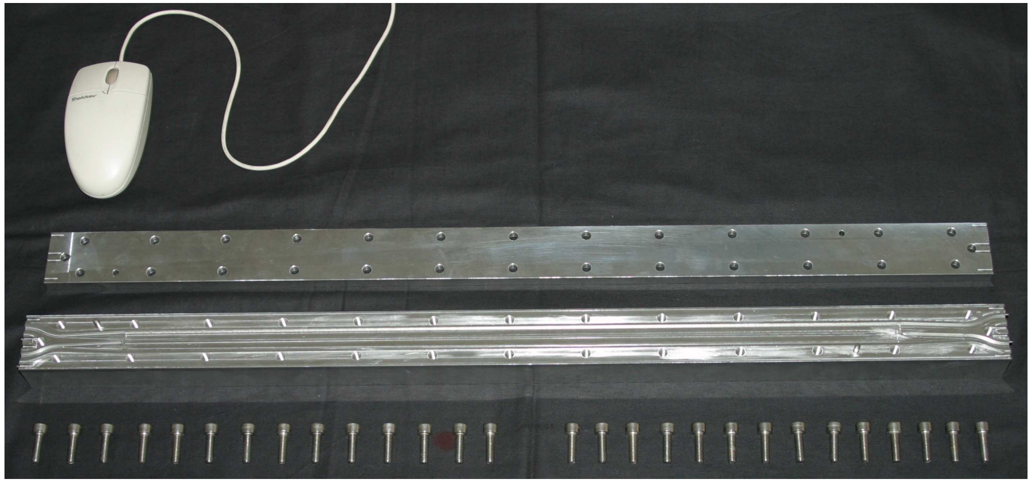


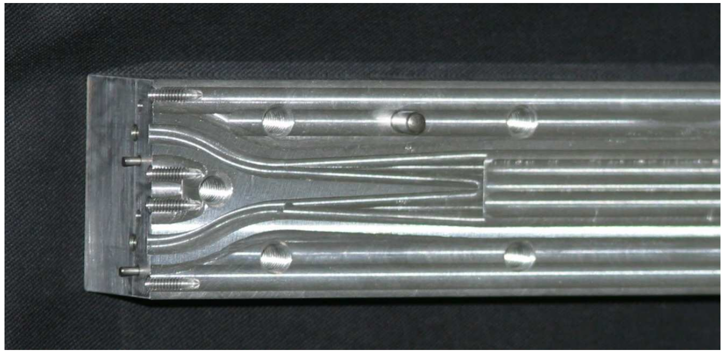
Electrical field (left) and power density (right) at the 75 GHz input

Pictures of the diplexers

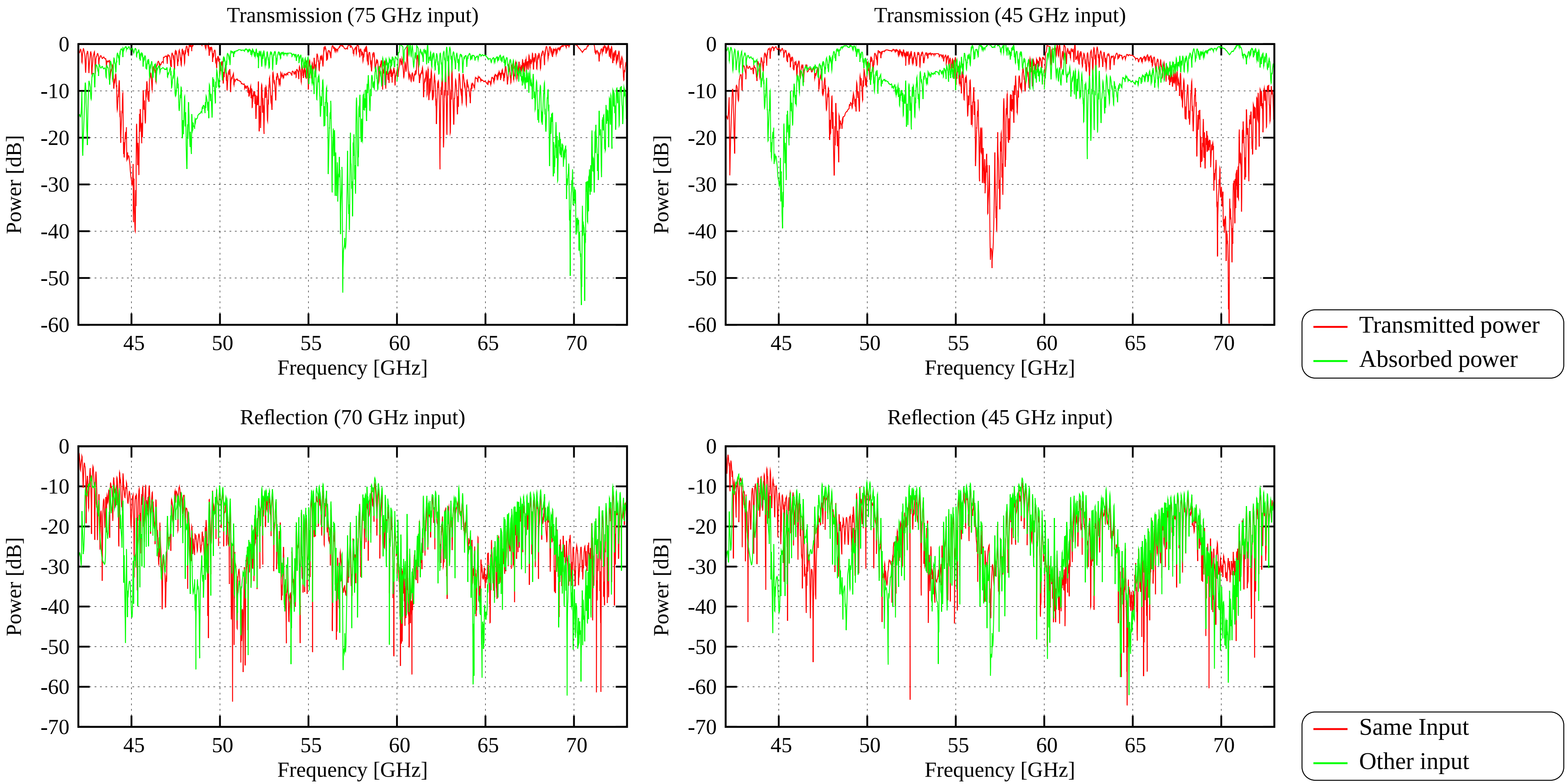




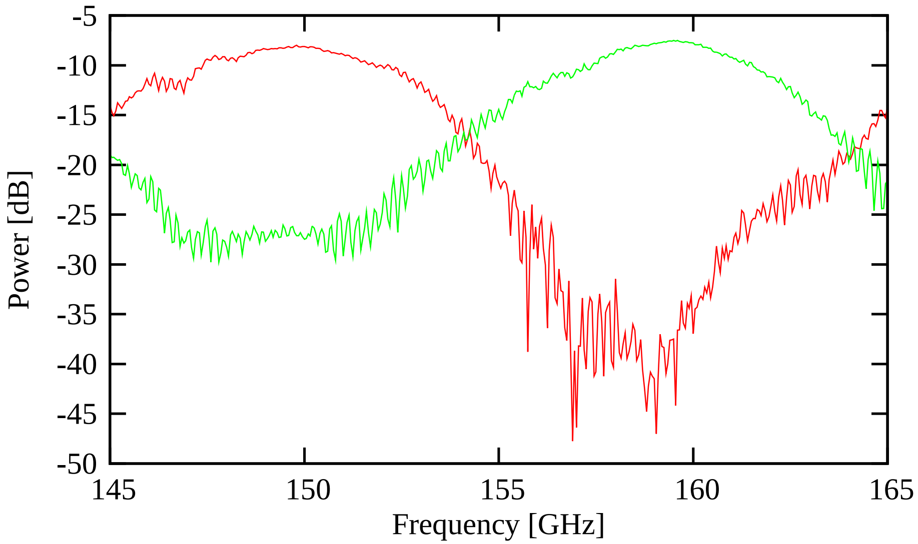


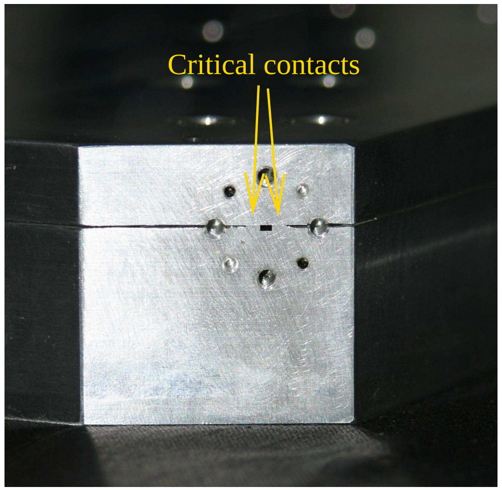


Experimental results (spatial diplexer)



Experimental results (angular diplexer)





Very high transmission loss (-8 dB/-7.5 dB)

Possible reason:

Waveguide height is very small (0.83 mm)

→ High losses of the modes (3.94 dB/m for $TE_{1,0}$, 19.55 dB/m for $TE_{17,0}$ @ 160 GHz)

→ Manufacturing tolerances cause high additional losses

Possible solution: Enlarge the height of the waveguide (e.g. 4 mm)

Conclusions

- *Proof of principle* was successful for both types of diplexers
- The transmission loss of the angular diplexer must be reduced
- The peak field strength in the angular diplexer is much higher than in the spatial diplexer (problems with high power operation).
- For low power application, both types of diplexers have similar theoretical characteristics with respect to geometry and efficiency.