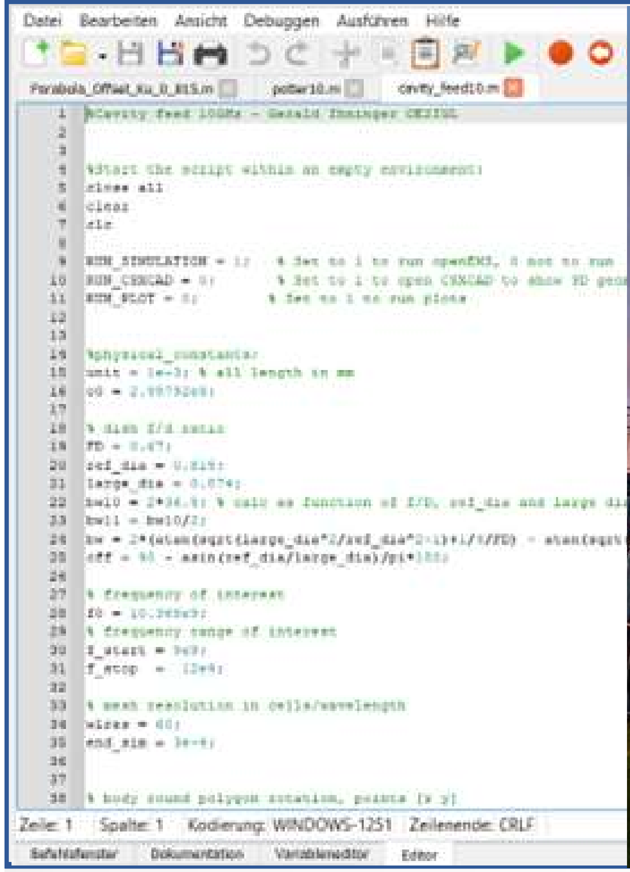
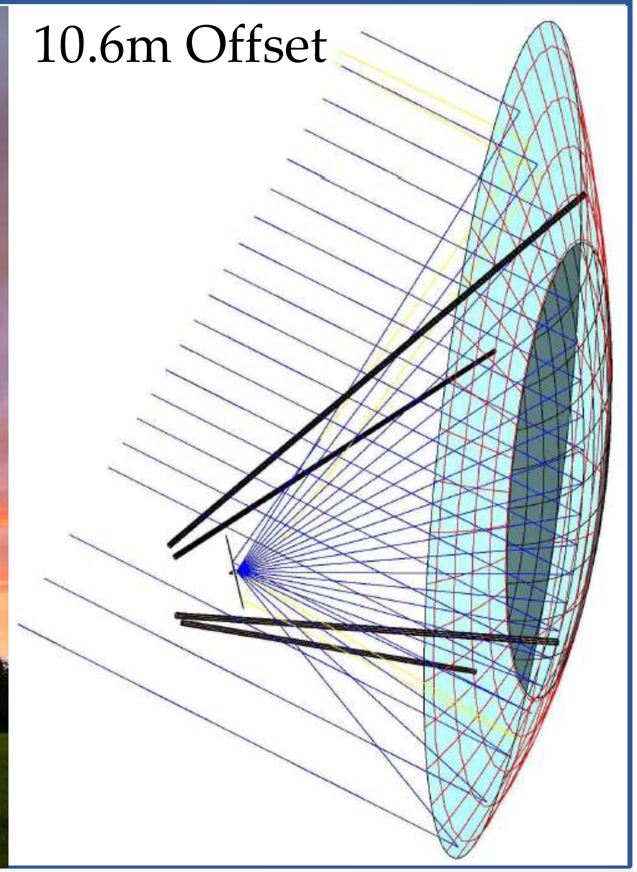




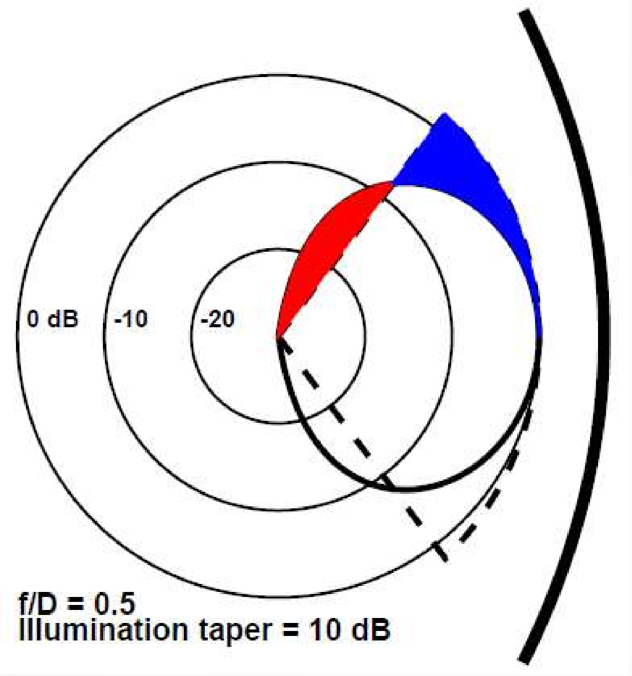



# Kostenlose Simulationen von Strahler und Reflektor für höchste Performance

*„Der beste Verstärker ist ein optimiertes Strahler/Reflektor System für höchste Performance“*

# Reflektor-Wirkungsgrade², die vom Strahler bestimmt werden

- $\eta_i$ ... illumination (Ausleuchtungs) Wirkungsgrad
- $\eta_s$ ... spillover (Überstrahlungs) Wirkungsgrad, aufgrund der Seitenkeulen



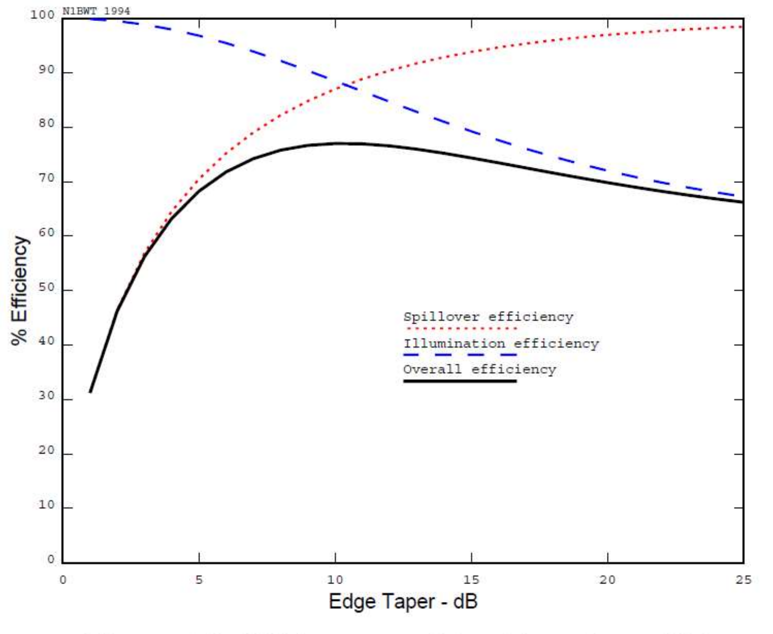



Figure 4-7. Efficiency vs. Edge Taper for a Dish



- $\eta_{xpol}$ ... cross polarisation (Kreuzpolarisations) Wirkungsgrad → Ziel: >99.5%
- $\eta_{phase}$ ... phase error (Phasenfehler) Wirkungsgrad → Ziel: >99.5%

$\eta_{aper} = \eta_i * \eta_s * \eta_{xpol} * \eta_{phase}$

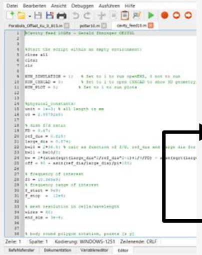
Gain [dB] = $10 \log (\pi^2 * D^2/\lambda^2 * \eta_{aper})$

- $\eta_{ges} = \eta_{aper} * \eta_{ohmic} * \eta_{RUZE} * \eta_{blocking} * \eta_{feedpos} * \eta_{impedance} * \ldots$

# Simulationskonzept mit OpenEMS[3] & GRASP-SE[4]

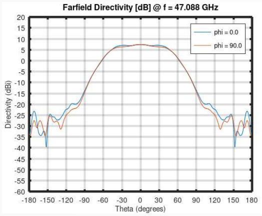
Strahler Anforderung
(f/D, Frequenz,...)

Strahlergeometrie



OpenEMS

free CST




Optimierter Strahler
für f/D, Frequenz

→ S11, Strahler Richtcharakteristik

Randausleuchtung

Strahler Richtcharakteristik

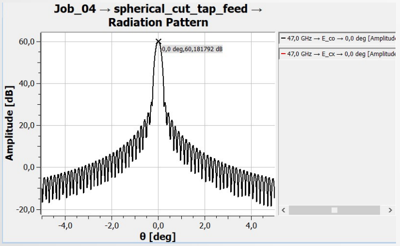
GRASP-SE:
sim Gauss beam
+ Reflektor

→ $\eta_s$ , gain
→ Spiegel pattern
→ HPBW
→ calc $\eta_i$ $\eta_{phase}$ $\eta_{xpol}$

Octave script
calc Strahler
+ Reflektor

→ $\eta_i$ , $\eta_s$ ,
→ $\eta_{xpol}$ , $\eta_{phase}$
→ gain, G/T
→ edge taper

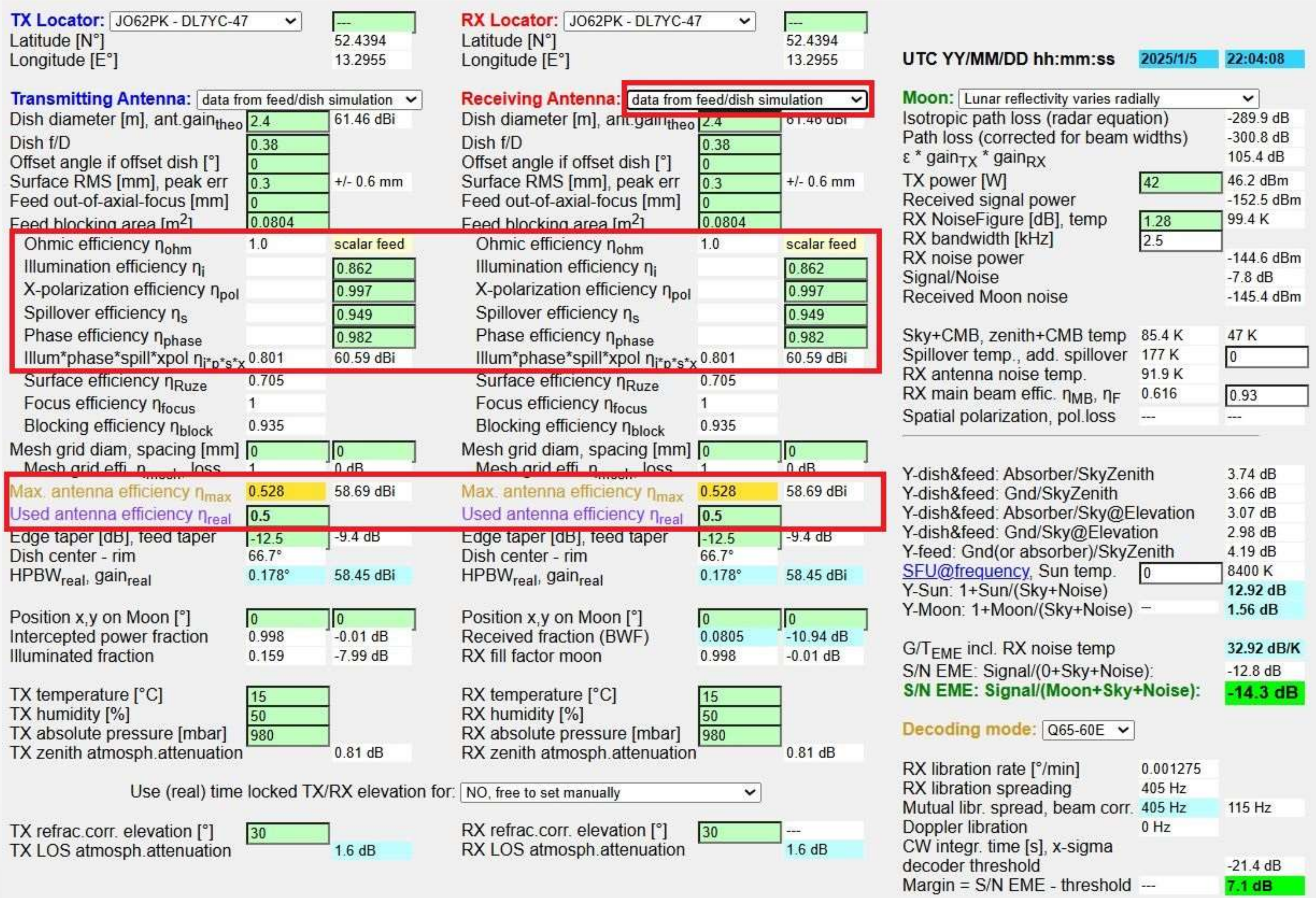
Joachim's
DF3GJ oder
W1GHZ
Tool




| half_opening_angle | f/D | eta_forward | spillover_loss | eta_spillover | eta_illumination | eta_xpol | eta_phase |
|---|---|---|---|---|---|---|---|
| 86.0° | 0.250 | <99.34% | 00.66% | 99.34% | 47.27% | 99.52% | 99.76% |
| 83.6° | 0.260 | <99.23% | 00.77% | 99.23% | 50.14% | 99.52% | 99.76% |
| 81.3° | 0.270 | <99.12% | 00.88% | 99.12% | 52.99% | 99.53% | 99.75% |
| 79.1° | 0.280 | <98.99% | 01.01% | 98.99% | 55.82% | 99.54% | 99.75% |
| 77.0° | 0.290 | <98.83% | 01.17% | 98.83% | 58.61% | 99.55% | 99.75% |
| 75.0° | 0.300 | <98.66% | 01.34% | 98.66% | 61.35% | 99.56% | 99.76% |
| 73.1° | 0.310 | <98.46% | 01.54% | 98.46% | 64.11% | 99.58% | 99.78% |
| 71.3° | 0.320 | <98.24% | 01.76% | 98.24% | 66.73% | 99.59% | 99.79% |

# Weiterverwendung im „EME Link Budget & Analysis Tool“ [1], OE2IGL

- https://wettersat.bplaced.net/EME/EME.html



| | | |
|---|---|---|
| TX Locator: | JO62PK - DL7YC-47 | --- |
| Latitude [N°] | | 52.4394 |
| Longitude [E°] | | 13.2955 |
| Transmitting Antenna: | data from feed/dish simulation | |
| Dish diameter [m], ant.gain$_{theo}$ | 2.4 | 61.46 dBi |
| Dish f/D | 0.38 | |
| Offset angle if offset dish [°] | 0 | |
| Surface RMS [mm], peak err | 0.3 | +/- 0.6 mm |
| Feed out-of-axial-focus [mm] | 0 | |
| Feed blocking area [m$^2$] | 0.0804 | |
| Ohmic efficiency $\eta_{ohm}$ | 1.0 | scalar feed |
| Illumination efficiency $\eta_i$ | | 0.862 |
| X-polarization efficiency $\eta_{pol}$ | | 0.997 |
| Spillover efficiency $\eta_s$ | | 0.949 |
| Phase efficiency $\eta_{phase}$ | | 0.982 |
| Illum*phase*spill*xpol $\eta_{i*p*s*x}$ | 0.801 | 60.59 dBi |
| Surface efficiency $\eta_{Ruze}$ | 0.705 | |
| Focus efficiency $\eta_{focus}$ | 1 | |
| Blocking efficiency $\eta_{block}$ | 0.935 | |
| Mesh grid diam, spacing [mm] | 0 | 0 |
| Mesh grid effi. $\eta_{mesh}$, loss | 1 | 0 dB |
| Max. antenna efficiency $\eta_{max}$ | 0.528 | 58.69 dBi |
| Used antenna efficiency $\eta_{real}$ | 0.5 | |
| Edge taper [dB], feed taper | -12.5 | -9.4 dB |
| Dish center - rim | 66.7° | |
| HPBW$_{real}$, gain$_{real}$ | 0.178° | 58.45 dBi |
| Position x,y on Moon [°] | 0 | 0 |
| Intercepted power fraction | 0.998 | -0.01 dB |
| Illuminated fraction | 0.159 | -7.99 dB |
| TX temperature [°C] | 15 | |
| TX humidity [%] | 50 | |
| TX absolute pressure [mbar] | 980 | |
| TX zenith atmosph.attenuation | | 0.81 dB |
| TX refrac.corr. elevation [°] | 30 | |
| TX LOS atmosph.attenuation | | 1.6 dB |

| | | |
|---|---|---|
| RX Locator: | JO62PK - DL7YC-47 | --- |
| Latitude [N°] | | 52.4394 |
| Longitude [E°] | | 13.2955 |
| Receiving Antenna: | data from feed/dish simulation | |
| Dish diameter [m], ant.gain$_{theo}$ | 2.4 | 61.46 dBi |
| Dish f/D | 0.38 | |
| Offset angle if offset dish [°] | 0 | |
| Surface RMS [mm], peak err | 0.3 | +/- 0.6 mm |
| Feed out-of-axial-focus [mm] | 0 | |
| Feed blocking area [m$^2$] | 0.0804 | |
| Ohmic efficiency $\eta_{ohm}$ | 1.0 | scalar feed |
| Illumination efficiency $\eta_i$ | | 0.862 |
| X-polarization efficiency $\eta_{pol}$ | | 0.997 |
| Spillover efficiency $\eta_s$ | | 0.949 |
| Phase efficiency $\eta_{phase}$ | | 0.982 |
| Illum*phase*spill*xpol $\eta_{i*p*s*x}$ | 0.801 | 60.59 dBi |
| Surface efficiency $\eta_{Ruze}$ | 0.705 | |
| Focus efficiency $\eta_{focus}$ | 1 | |
| Blocking efficiency $\eta_{block}$ | 0.935 | |
| Mesh grid diam, spacing [mm] | 0 | 0 |
| Mesh grid effi. $\eta_{mesh}$, loss | 1 | 0 dB |
| Max. antenna efficiency $\eta_{max}$ | 0.528 | 58.69 dBi |
| Used antenna efficiency $\eta_{real}$ | 0.5 | |
| Edge taper [dB], feed taper | -12.5 | -9.4 dB |
| Dish center - rim | 66.7° | |
| HPBW$_{real}$, gain$_{real}$ | 0.178° | 58.45 dBi |
| Position x,y on Moon [°] | 0 | 0 |
| Received fraction (BWF) | 0.0805 | -10.94 dB |
| RX fill factor moon | 0.998 | -0.01 dB |
| RX temperature [°C] | 15 | |
| RX humidity [%] | 50 | |
| RX absolute pressure [mbar] | 980 | |
| RX zenith atmosph.attenuation | | 0.81 dB |
| RX refrac.corr. elevation [°] | 30 | --- |
| RX LOS atmosph.attenuation | | 1.6 dB |

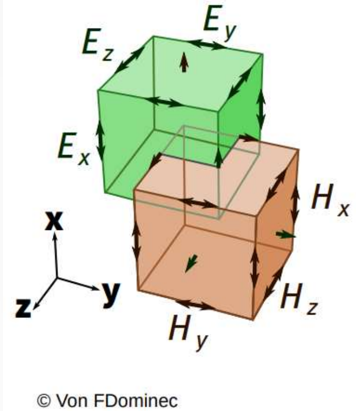
Use (real) time locked TX/RX elevation for: NO, free to set manually

| | | |
|---|---|---|
| UTC YY/MM/DD hh:mm:ss | 2025/1/5 | 22:04:08 |
| Moon: | Lunar reflectivity varies radially | |
| Isotropic path loss (radar equation) | | -289.9 dB |
| Path loss (corrected for beam widths) | | -300.8 dB |
| ε * gain$_{TX}$ * gain$_{RX}$ | | 105.4 dB |
| TX power [W] | 42 | 46.2 dBm |
| Received signal power | | -152.5 dBm |
| RX NoiseFigure [dB], temp | 1.28 | 99.4 K |
| RX bandwidth [kHz] | 2.5 | |
| RX noise power | | -144.6 dBm |
| Signal/Noise | | -7.8 dB |
| Received Moon noise | | -145.4 dBm |
| Sky+CMB, zenith+CMB temp | 85.4 K | 47 K |
| Spillover temp., add. spillover | 177 K | 0 |
| RX antenna noise temp. | 91.9 K | |
| RX main beam effic. $\eta_{MB}$, $\eta_F$ | 0.616 | 0.93 |
| Spatial polarization, pol.loss | --- | --- |
| Y-dish&feed: Absorber/SkyZenith | | 3.74 dB |
| Y-dish&feed: Gnd/SkyZenith | | 3.66 dB |
| Y-dish&feed: Absorber/Sky@Elevation | | 3.07 dB |
| Y-dish&feed: Gnd/Sky@Elevation | | 2.98 dB |
| Y-feed: Gnd(or absorber)/SkyZenith | | 4.19 dB |
| SFU@frequency, Sun temp. | 0 | 8400 K |
| Y-Sun: 1+Sun/(Sky+Noise) | | 12.92 dB |
| Y-Moon: 1+Moon/(Sky+Noise) | – | 1.56 dB |
| G/T$_{EME}$ incl. RX noise temp | | 32.92 dB/K |
| S/N EME: Signal/(0+Sky+Noise): | | -12.8 dB |
| S/N EME: Signal/(Moon+Sky+Noise): | | -14.3 dB |
| Decoding mode: | Q65-60E | |
| RX libration rate [°/min] | 0.001275 | |
| RX libration spreading | 405 Hz | |
| Mutual libr. spread, beam corr. | 405 Hz | 115 Hz |
| Doppler libration | 0 Hz | |
| CW integr. time [s], x-sigma | | |
| decoder threshold | | -21.4 dB |
| Margin = S/N EME - threshold | --- | 7.1 dB |

# Strahlersimulation mit OpenEMS[3]

- OpenEMS ist ein **<u>kostenloses</u>**, open-source Tool von Thorsten Liebig
- FDTD Simulator, der die Maxwellgleichungen im Zeitbereich löst

| Gnu Octave / MATLAB (neu: Python) | | |
|---|---|---|
| openEMS | CSXCAD | NF2FF |
| Hauptprogramm<br><br>Modelliert die Maxwell-Gleichungen | Bibliothek + Hilfsprogramm<br><br>modelliert und verwaltet die Geometrie | Hilfsprogramm<br><br>berechnet abgestrahlte Felder (z.B. Richtdiagramm) |



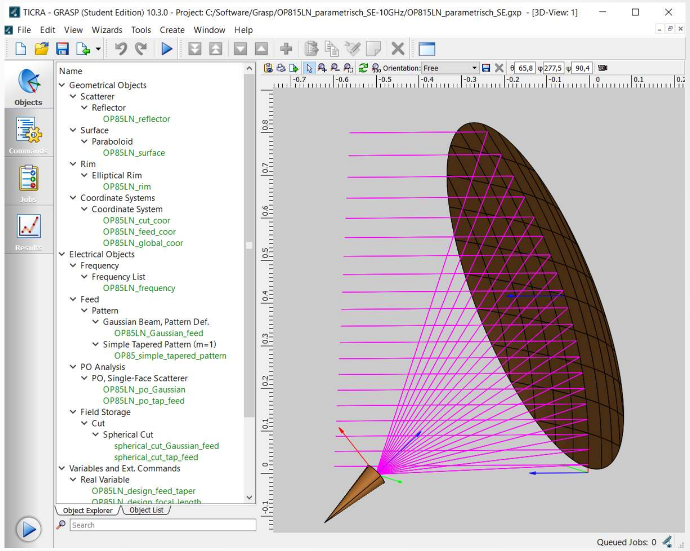

- Windows & Linux, multi-threading fähig
- Matlab/<u>Octave</u> und Phyton werden als flexibles scripting Interface verwendet

**Einschränkungen:**

- Scripting ist <u>nicht selbsterklärend, keine user-freundliche Oberfläche</u>
  Benötigt grundlegendes Basiswissen in der Modelierung (z.B. Meshing)
- Kann schnell sehr ressourcenfressend werden: z.B. 10 GHz
  Strahler + 1.2 m Spiegel → 32 GB RAM, RAM speed ist limitierender Faktor
  Strahler + 2.4 m Spiegel → benötigt bereits 256 GB RAM und 16x Laufzeit

# Strahler/Reflektorsimulation mit GRASP-SE[4]

- GRASP ist seit >45 Jahren der Industriestandard für Reflektorantennen
- Mit GRASP-SE ist eine **kostenlose** Version verfügbar




**Einschränkungen:**

- Umfang ist limitiert, über workarounds kann einiges umgangen werden
- Resultate unterscheiden sich zur Vollversion nur minimal (max. 0.1 dB Gewinn)
- Feed kann in der SE Version mitsimuliert werden, aber nur als „Gauß-Beam“ bzw. „Simple tapered Beam“


Mein „Lehrer“, Willi Göldi[8] HB9PZK, hat mir die Software nahegelegt.
Er entwickelt seit 40 Jahren hocheffiziente Deep-Space Systeme (Strahler/Reflektor) bis 35m

# Strebt das Beste an!
# Im Amateurbereich ist Performance machbar

**Strahler/Reflektor Wirkungsgrad $\eta_{aper}$ :**

- **> 90%** **professionelle Anwendungen im high-tec Bereich**
- **> 80%** **sehr gut für Amateure**
- > 75% gut
- 65-75% passt, geht aber besser
- 50-65% „na ja“
- <50% schlecht („Dosenstrahler“)

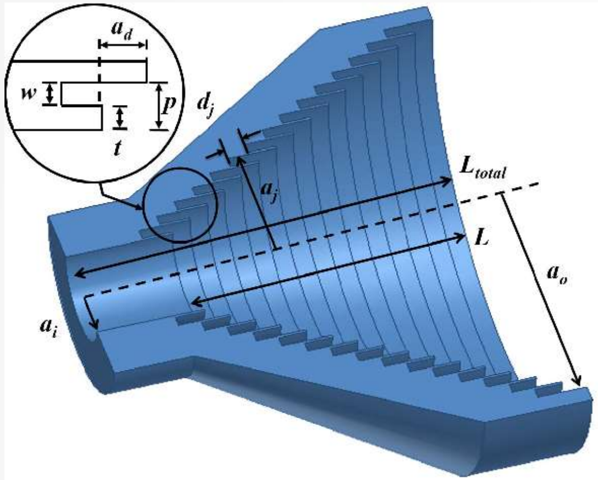
**Verbesserung 10% (≙ ~1 dB NF Reduzierung) → + 1.3 dB SNR bei EME**
**+ 0.7 dB Sonnenrauschen**

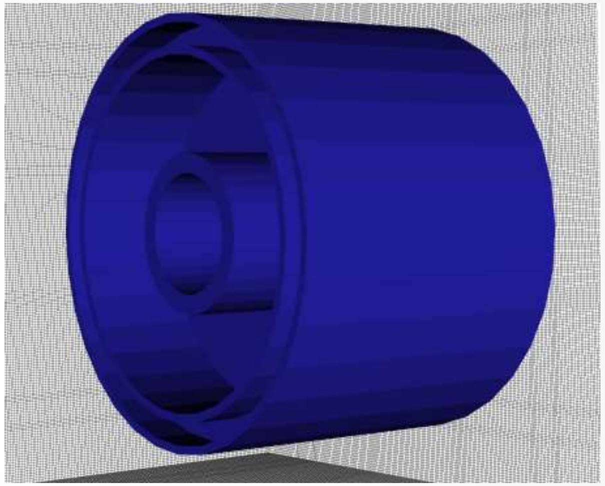
- In der Regel wird nicht auf Tx (max Gain) optimiert.
  Bei RX-Optimierung (hohes G/T) muss man kleine Einbussen bei $\eta_{aper}$ in Kauf nehmen, dafür sind die Seitenkeulen wesentlich geringer.

- $\eta_{ges}$ ist durch die zusätzlichen Verluste geringer,
  vor allem bei Frequenzen >10 GHz.

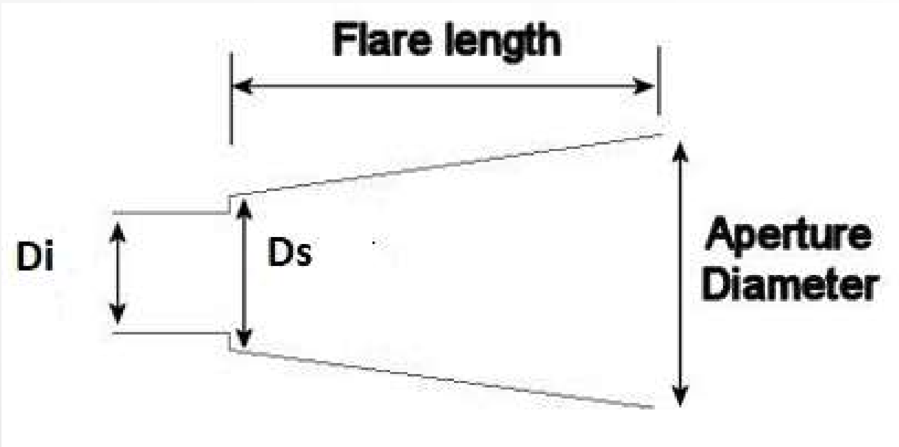
# Meine Strahlerfavoriten und Designguide[5] für einfache und schnelle Berechnung

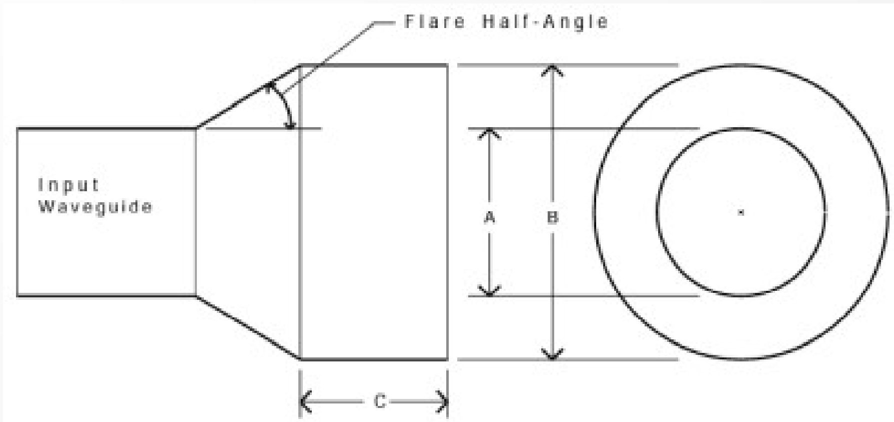
- Verschiedene Strahlertypen auf max. Wirkungsgrad simuliert
- Mit Rillenhorn- und Cavitystrahler[7] ist ein Wirkungsgrad **>80%** realisierbar



- Mit Pickett-Potter und W2IMU sind bis zu **80%** möglich



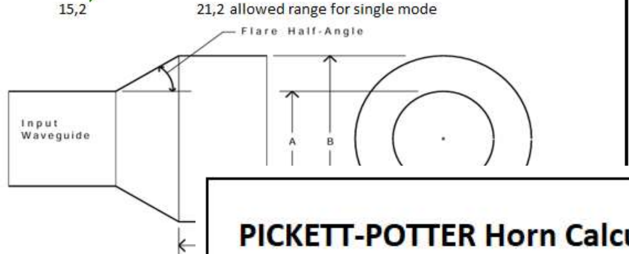



# Meine Strahlerfavoriten und Designguide[5] für einfache und schnelle Berechnung

- Nicht alle Designs sind für jedes f/D geeignet, DMH für f/D>0.55

**W2IMU Dual Mode Horn Calculator:** enter yellow fields — OE2IGL, 2024-10-06

| | | | | | |
|---|---|---|---|---|---|
| **Frequency:** | 24,048 | GHz | | | |
| **f/D =** | 0,75 | only valid for prime focus, for offset it is lower : | 0,660 | | |
| **dish opening angle :** | 74,1 | ° | | | |
| **Cutoff =** | 18,5 | GHz | | | |
| **Lambda =** | 12,47 | mm | | | |
| **A =** | 9,49 | mm | 8,7 | 10,1 | allowed range for cutoff |
| **B =** | 21,03 | mm | 15,2 | 21,2 | allowed range for single mode |
| **C =** | 40,14 | mm | | | |
| **Alpha =** | 26,4 | ° | | | |
| **fmin =** | 21,3 | GHz | | | |
| **fmax =** | 29,1 | GHz | | | |
| **Lamdag =** | 19,54 | | | | |

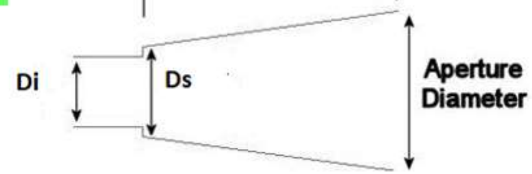



efficiencies between 77% (f/D 0.5) and 80% (f/D 0.8) are possible
use EME tool to calculate dish opening angle (= dishcenter-to-rim *2) f
**note**: based on W1GHZ work and improved by own simulations with O

**PICKETT-POTTER Horn Calculator:** enter yellow fields — OE2IGL, 2024-10-03

| | Apertur R | L flare |
|---|---|---|
| | 0,9278233 | 2,811 |
| | 0,0% | 2,811 |

| | | | |
|---|---|---|---|
| **frequency :** | 24,048 | GHz | |
| **dish opening angle :** | 70,2 | ° | |
| **f/D =** | 0,79 | only valid for prime focus, for offset it is lower : ~ | 0,70 |
| **wavelength =** | 12,48 | mm | |
| **Di =** | 12,72 | mm | |
| **Ds =** | 16,22 | mm | |
| **D aperture =** | 23,15 | mm | |
| **L flare =** | 35,07 | mm | |

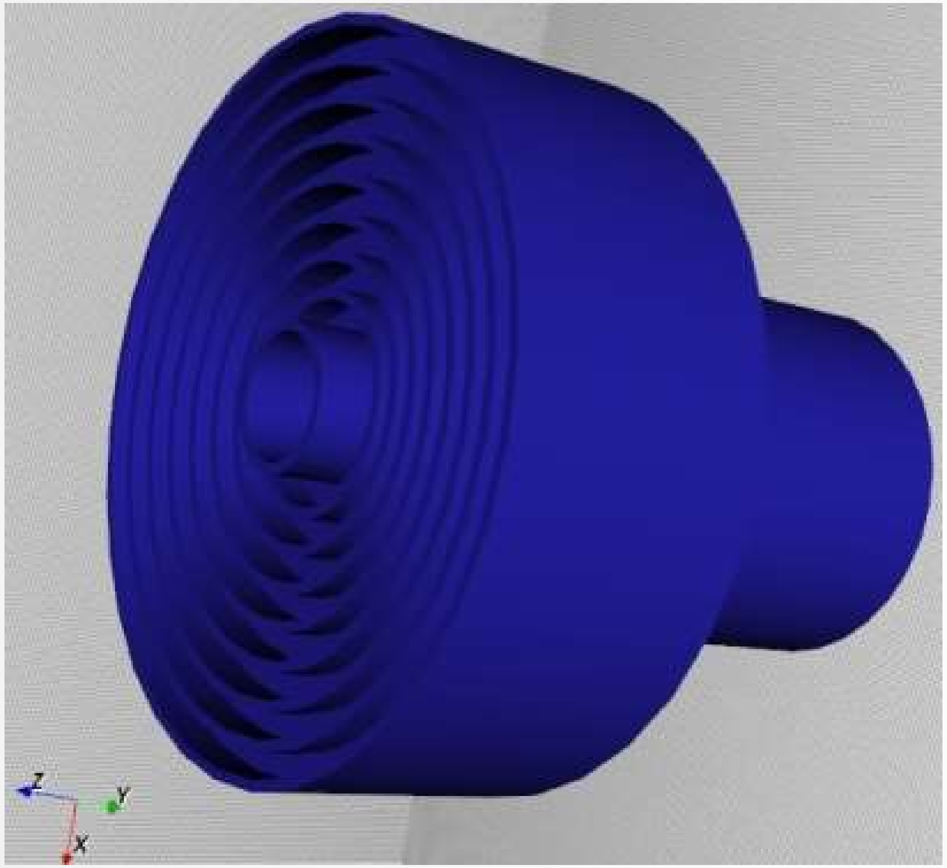



use EME tool to calculate dish opening angle (= dishcenter-to-rim *2) for given f/D, optimized for -10 dB horn beam width
efficiencies between 78% (f/D 0.6) and 81% (f/D >1.0) are possible
**note**: based on Thomas Milligan's work and checked by own simulations with OpenEMS

- https://wettersat.bplaced.net/DualModeHorn-design-guide.xlsx

# Hocheffizienter 47 GHz Rillenhornstrahler für DL7YC erreicht max. 82% Wirkungsgrad

- Simulation mit OpenEMS von Luis Cupido CT1DMK



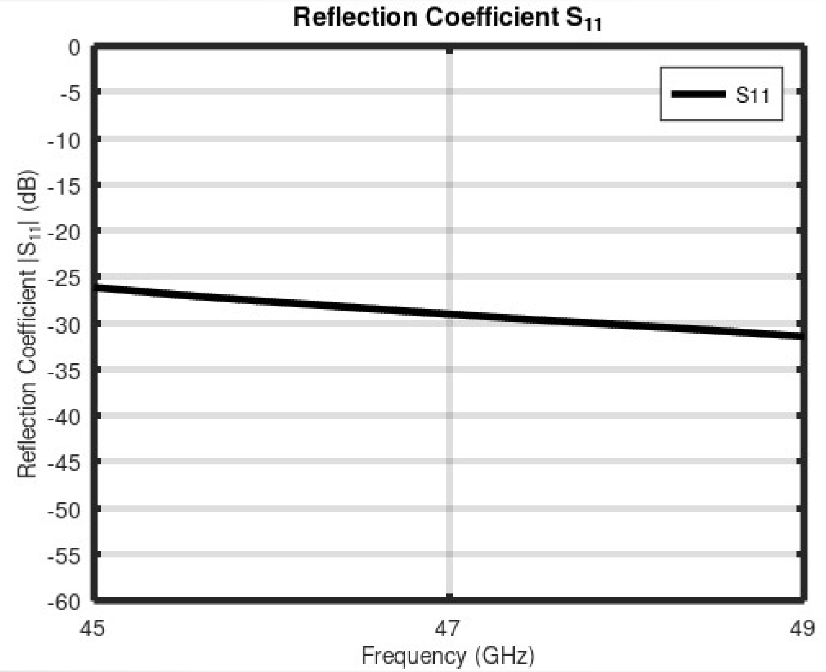

- Moon Noise auf ~2.1 dB gestiegen (+0.3 ... 0.4 dB)

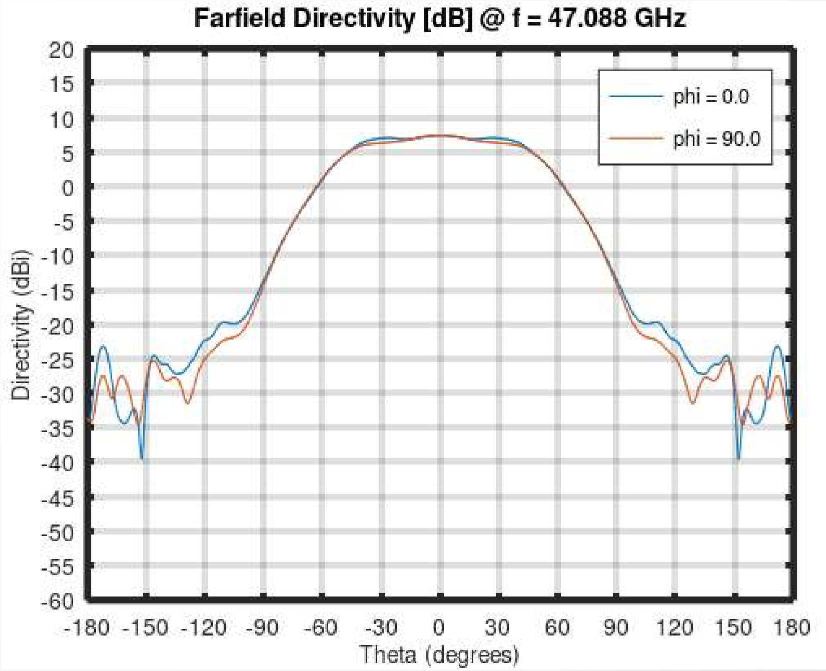
# Hocheffizienter 47 GHz Rillenhornstrahler für DL7YC ist auf Rx (hohes G/T) optimiert

```
phase center E-field            = -0.181 lambda
phase center H-field            = -0.065 lambda
phase center "-"=inside aper.   = -0.78 mm
```

| half_opening_angle | f/D | eta_forward | spillover_loss | eta_spillover | eta_illumination | eta_xpol | eta_phas | …or_gain | feed_taper_E | feed_taper_H | edge_taper | G/T (45° |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 90.0° | 0.250 | <99.64% | 00.36% | 99.64% | 55.74% | 98.06% | 97.19% | 1 dBi | -21.0dB | -21.7dB | -27.3dB | 33.36 dB |
| 87.8° | 0.260 | <99.55% | 00.45% | 99.55% | 59.04% | 98.06% | 97.83% | 8 dBi | -19.7dB | -20.1dB | -25.6dB | 33.63 dB |
| 85.6° | 0.270 | <99.42% | 00.58% | 99.42% | 62.18% | 98.06% | 98.39% | 3 dBi | -18.3dB | -18.7dB | -23.9dB | 33.87 dB |
| 83.5° | 0.280 | <99.25% | 00.75% | 99.25% | 65.19% | 98.07% | 98.83% | 4 dBi | -17.1dB | -17.3dB | -22.3dB | 34.09 dB |
| 81.5° | 0.290 | <99.05% | 00.95% | 99.05% | 68.05% | 98.08% | 99.16% | 3 dBi | -15.9dB | -16.1dB | -20.8dB | 34.27 dB |
| 79.6° | 0.300 | <98.79% | 01.21% | 98.79% | 70.77% | 98.09% | 99.40% | 0 dBi | -14.8dB | -15.0dB | -19.5dB | 34.44 dB |
| 77.8° | 0.310 | <98.48% | 01.52% | 98.48% | 73.37% | 98.10% | 99.56% | 6 dBi | -13.9dB | -14.0dB | -18.3dB | 34.58 dB |
| 76.0° | 0.320 | <98.11% | 01.89% | 98.11% | 75.73% | 98.12% | 99.66% | 8 dBi | -13.1dB | -13.1dB | -17.2dB | 34.69 dB |
| 74.3° | 0.330 | <97.68% | 02.32% | 97.68% | 77.97% | 98.13% | 99.72% | 9 dBi | -12.3dB | -12.3dB | -16.2dB | 34.79 dB |
| 72.7° | 0.340 | <97.21% | 02.79% | 97.21% | 80.13% | 98.15% | 99.75% | 9 dBi | -11.6dB | -11.5dB | -15.3dB | 34.88 dB |
| 71.1° | 0.350 | <96.65% | 03.35% | 96.65% | 82.03% | 98.17% | 99.77% | 7 dBi | -10.9dB | -10.8dB | -14.4dB | 34.94 dB |
| 69.6° | 0.360 | <96.05% | 03.95% | 96.05% | 83.86% | 98.20% | 99.77% | 4 dBi | -10.3dB | -10.1dB | -13.6dB | 35.00 dB |
| 68.1° | 0.370 | <95.35% | 04.65% | 95.35% | 85.44% | 98.22% | 99.77% | 9 dBi | -09.6dB | -09.5dB | -12.8dB | 35.03 dB |
| 66.7° | 0.380 | <94.62% | 05.38% | 94.62% | 86.99% | 98.24% | 99.76% | 4 dBi | -09.1dB | -08.9dB | -12.1dB | 35.05 dB |
| 65.3° | 0.390 | <93.79% | 06.21% | 93.79% | 88.29% | 98.27% | 99.76% | 6 dBi | -08.5dB | -08.3dB | -11.4dB | 35.06 dB |
| 64.0° | 0.400 | <92.92% | 07.08% | 92.92% | 89.58% | 98.30% | 99.75% | 9 dBi | -08.0dB | -07.7dB | -10.7dB | 35.06 dB |
| 62.7° | 0.410 | <91.95% | 08.05% | 91.95% | 90.64% | 98.33% | 99.75% | 9 dBi | -07.5dB | -07.2dB | -10.1dB | 35.04 dB |
| 61.5° | 0.420 | <90.96% | 09.04% | 90.96% | 91.72% | 98.35% | 99.75% | 0 dBi | -07.0dB | -06.7dB | -09.5dB | 35.01 dB |
| 60.3° | 0.430 | <89.85% | 10.15% | 89.85% | 92.57% | 98.39% | 99.75% | 9 dBi | -06.5dB | -06.2dB | -08.9dB | 34.97 dB |
| 59.2° | 0.440 | <88.74% | 11.26% | 88.74% | 93.50% | 98.42% | 99.75% | 8 dBi | -06.0dB | -05.8dB | -08.3dB | 34.94 dB |

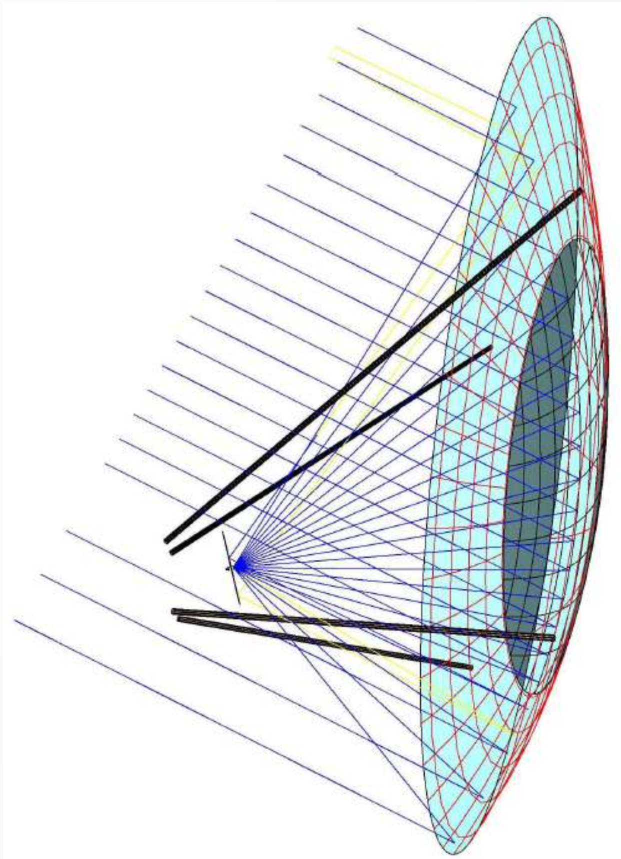
79.84%
80.67%
[illegible]
81.63%
81.74%
81.85%
[illegible]
81.46%



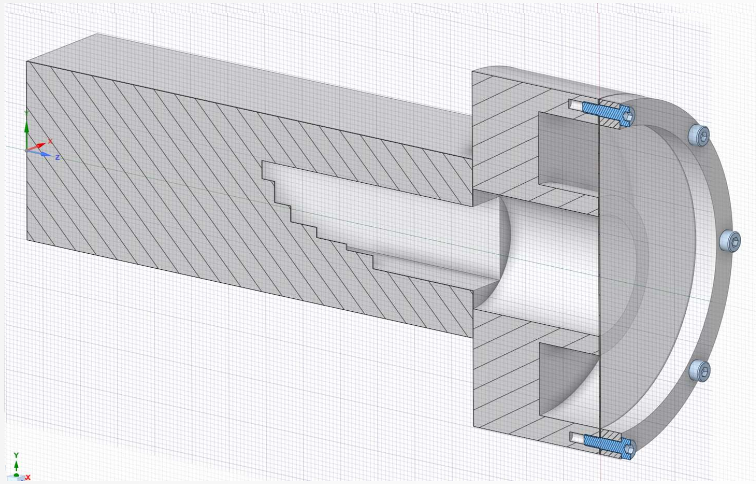
# Strahleroptimierung - 10.6 m Offset - OE9ERC

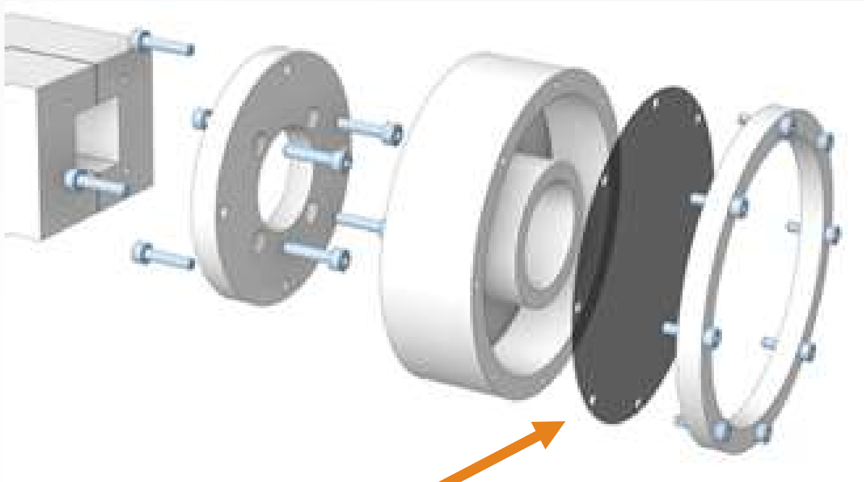
- Gemeinschaftsarbeit mit Willi HB9PZK und Erich OE9ERC
  - bestehende Strahler zeigten nur max. 60% in der Simulation/Realität
  - es wird ein optimierter Strahler für 10 GHz, f/D = 0.414 benötigt



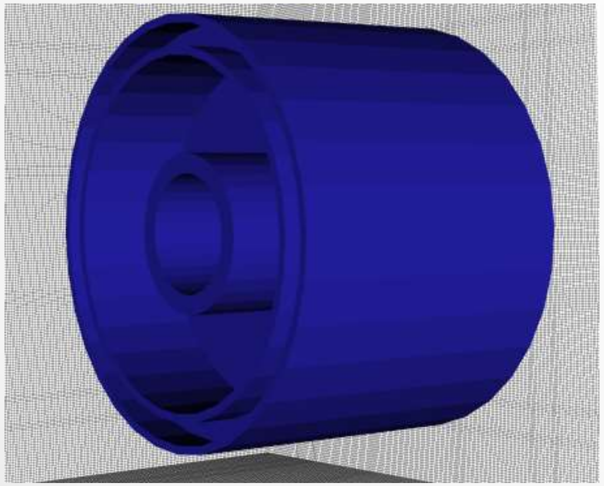
# Strahleroptimierung - 10.6 m Offset - OE9ERC

- Nach ersten Recherchen fiel die Wahl auf einen Cavity-Strahler Simulation ergab max. 82% Wirkungsgrad mit dem Septum





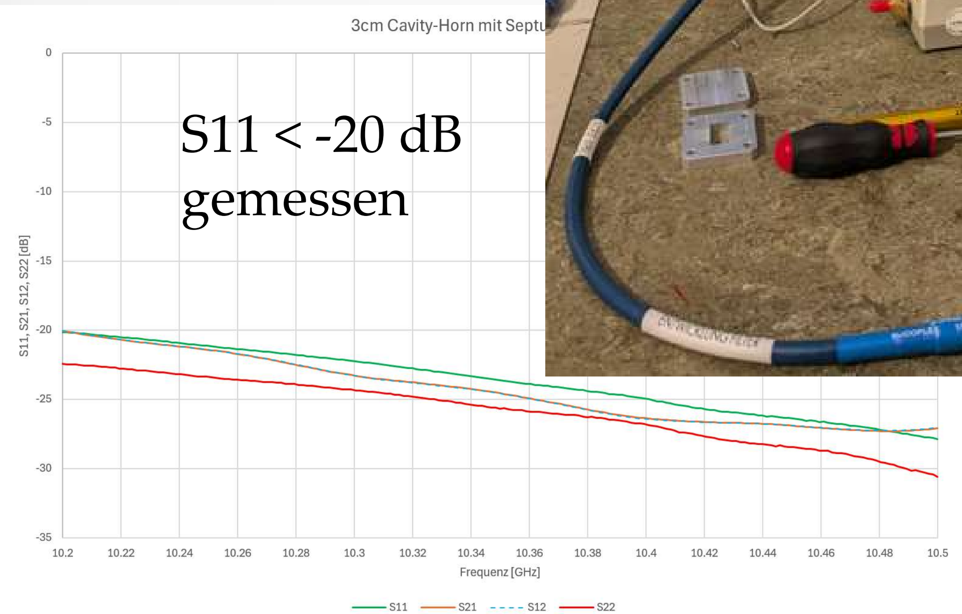
- Version 2 mit λ/4 Rille im Außenring erreicht sogar max. 83.2%

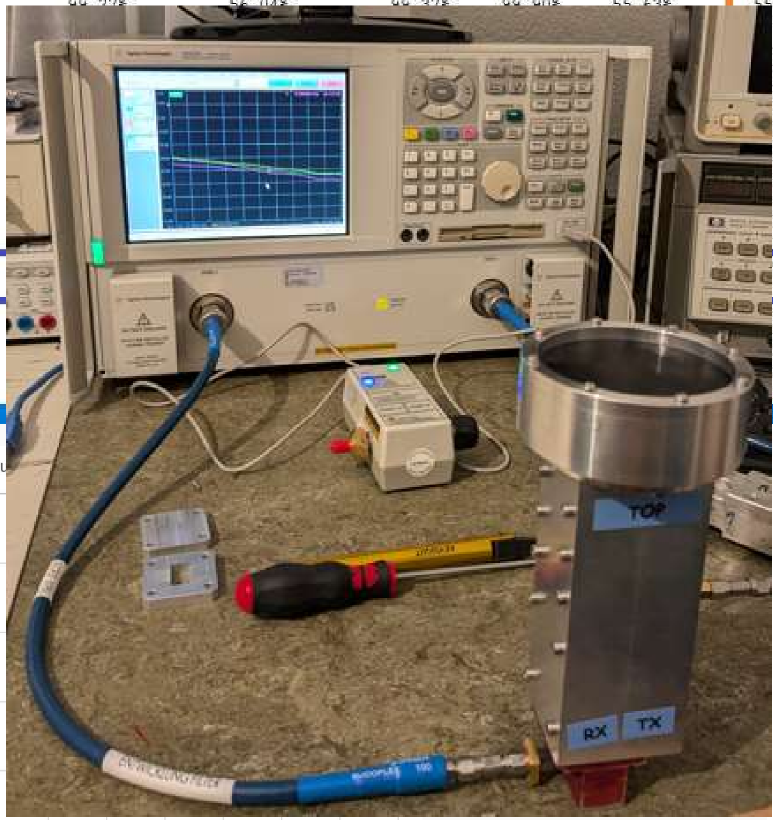


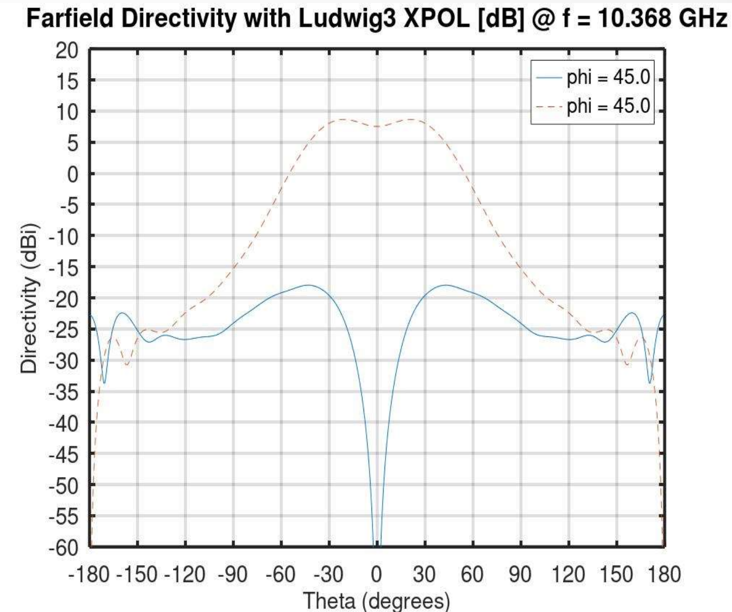
# Strahleroptimierung - 10.6 m Offset - OE9ERC

- Wir haben auf Rx optimiert -> immer noch 79% statt 82% Wirkungsgrad
- **Vorteil:** G/T ist höher aufgrund der stark reduzierten Seitenkeulen

| half_opening_angle | f/D | eta_forward | spillover_loss | eta_spillover | eta_illumination | eta_xpol | eta_phase | eta_s*eta_i | eta_aper | reflector_gain | feed_taper_E | feed_taper_H | edge_taper | G/T (45°) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 86.0° | 0.250 | <99.64% | 00.36% | 99.64% | 44.59% | 99.34% | 99.88% | 44.43% | 44.09% | 57.68 dBi | -22.7dB | -25.8dB | -25.1dB | 34.10 dB |
| 83.6° | 0.260 | <99.57% | 00.43% | 99.57% | 47.47% | 99.35% | 99.89% | 47.27% | 46.91% | 57.95 dBi | -21.8dB | -25.0dB | -24.3dB | 34.37 dB |
| 81.3° | 0.270 | <99.48% | 00.52% | 99.48% | 50.34% | 99.36% | 99.90% | 50.08% | 49.71% | 58.20 dBi | -20.8dB | -24.3dB | -23.6dB | 34.62 dB |
| 79.1° | 0.280 | <99.39% | 00.61% | 99.39% | 53.20% | 99.36% | 99.90% | 52.87% | 52.48% | 58.44 dBi | -19.9dB | -23.7dB | -22.9dB | 34.85 dB |
| 77.0° | 0.290 | <99.27% | 00.73% | 99.27% | 56.04% | 99.37% | 99.90% | 55.63% | 55.22% | 58.66 dBi | -18.9dB | -23.1dB | -22.2dB | 35.06 dB |
| 75.0° | 0.300 | <99.14% | 00.86% | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | .97% | 58.87 dBi | -18.0dB | -22.4dB | -21.5dB | 35.27 dB |
| 73.1° | 0.310 | <98.99% | 01.01% | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | .72% | 59.07 dBi | -17.1dB | -21.5dB | -20.8dB | 35.46 dB |
| 71.3° | 0.320 | <98.82% | 01.18% | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | .30% | 59.25 dBi | -16.3dB | -20.6dB | -20.1dB | 35.63 dB |
| 69.5° | 0.330 | <98.62% | 01.38% | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | .70% | 59.42 dBi | -15.4dB | -19.6dB | -19.4dB | 35.78 dB |
| 67.8° | 0.340 | <98.38% | 01.62% | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | .00% | 59.56 dBi | -14.6dB | -18.6dB | -18.7dB | 35.92 dB |
| 66.2° | 0.350 | <98.12% | 01.88% | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | .19% | 59.70 dBi | -13.8dB | -17.7dB | -18.0dB | 36.04 dB |
| 64.6° | 0.360 | <97.80% | 02.20% | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | .14% | 59.82 dBi | -13.1dB | -16.7dB | -17.3dB | 36.14 dB |
| 63.2° | 0.370 | <97.47% | 02.53% | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | .14% | 59.94 dBi | -12.4dB | -15.9dB | -16.7dB | 36.25 dB |
| 61.7° | 0.380 | <97.06% | 02.94% | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | .71% | 60.03 dBi | -11.6dB | -15.0dB | -16.0dB | 36.32 dB |
| 60.4° | 0.390 | <96.64% | 03.36% | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | .36% | 60.13 dBi | -11.0dB | -14.2dB | -15.4dB | 36.39 dB |
| 59.0° | 0.400 | <96.11% | 03.89% | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | .52% | 60.19 dBi | -10.3dB | -13.3dB | -14.6dB | 36.43 dB |
| 57.8° | 0.410 | <95.59% | 04.41% | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | .83% | 60.26 dBi | -09.8dB | -12.6dB | -14.1dB | 36.47 dB |
| 56.6° | 0.420 | <95.00% | 05.00% | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | .86% | 60.32 dBi | -09.2dB | -11.9dB | -13.3dB | 36.50 dB |
| 55.4° | 0.430 | <94.33% | 05.67% | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | .57% | 60.36 dBi | -08.6dB | -11.1dB | -12.7dB | 36.50 dB |
| 54.3° | 0.440 | <93.63% | 06.37% | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | .27% | 60.39 dBi | -08.1dB | -10.5dB | -12.0dB | 36.50 dB |
| 53.2° | 0.450 | <92.85% | 07.15% | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | .68% | 60.41 dBi | -07.6dB | -09.8dB | -11.4dB | 36.48 dB |
| 52.1° | 0.460 | <91.98% | 08.02% | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | .77% | 60.42 dBi | -07.2dB | -09.2dB | -10.7dB | 36.45 dB |
| 51.1° | 0.470 | <91.10% | 08.90% | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | .91% | 60.43 dBi | -06.7dB | -08.7dB | -10.1dB | 36.41 dB |
| 50.2° | 0.480 | <90.23% | 09.77% | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | .15% | 60.44 dBi | -06.3dB | -08.2dB | -09.6dB | 36.38 dB |

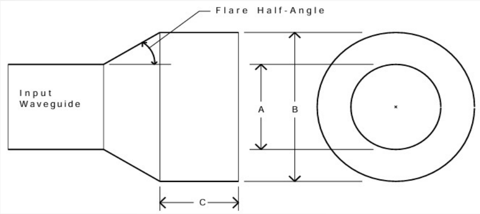


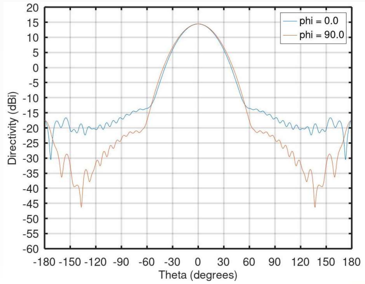



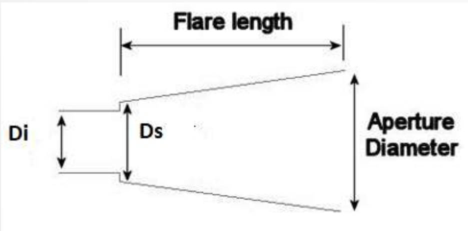
# Hocheffizienter W2IMU & Pickett-Potter Strahler für 47 GHz mit 80% Wirkungsgrad in Entwicklung/Bau

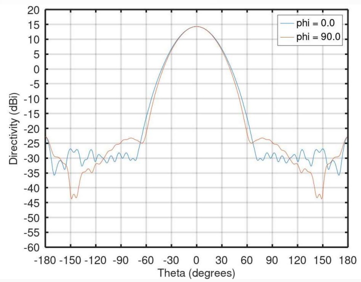
- Gemeinschaftsarbeit mit Ivan IZ0JNY https://www.iz0jny.it/
- Inklusive λ/4 Anpassplättchen für WR22/WR19
- Öffnungswinkel 74°, (f/D ~ 0.66 bei einem Offset), Rx optimiert




| half_opening_angle | f/D | eta_forward | spillover_loss | eta_spillover | eta_illumination | eta_xpol | eta_phase | eta_s*eta_i | eta_aper | reflector_gain |
|---|---|---|---|---|---|---|---|---|---|---|
| 37.1° | 0.660 | <94.03% | 05.97% | 94.03% | 83.38% | 99.35% | 99.93% | 78.40% | 77.84% | 54.35 dBi |
| 36.5° | 0.670 | <93.51% | 06.49% | 93.51% | 83.88% | 99.35% | 99.93% | 78.44% | 77.88% | 54.36 dBi |
| 36.0° | 0.680 | <93.05% | 06.95% | 93.05% | 84.64% | 99.35% | 99.93% | 78.76% | 78.19% | 54.37 dBi |
| 35.5° | 0.690 | <92.56% | 07.44% | 92.56% | 85.31% | 99.35% | 99.93% | 78.97% | 78.39% | 54.38 dBi |
| 35.0° | 0.700 | <92.04% | 07.96% | 92.04% | 85.90% | 99.35% | 99.93% | 79.06% | 78.48% | 54.39 dBi |
| 34.6° | 0.710 | <91.59% | 08.41% | 91.59% | 86.80% | 99.35% | 99.92% | 79.50% | 78.92% | 54.41 dBi |
| 34.1° | 0.720 | <91.01% | 08.99% | 91.01% | 87.22% | 99.34% | 99.92% | 79.37% | 78.79% | 54.41 dBi |

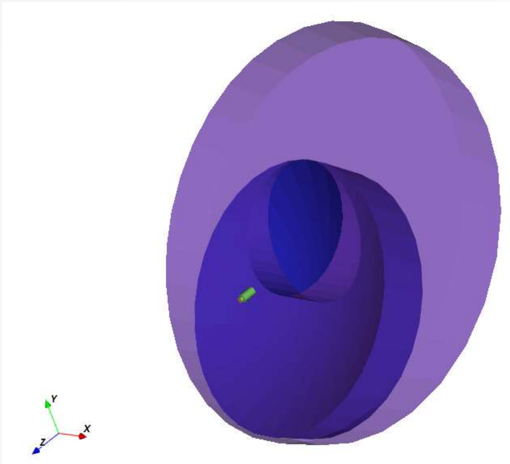


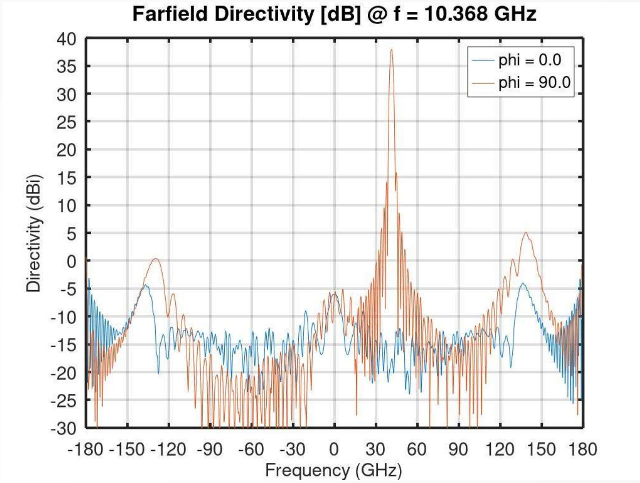




| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 37.1° | 0.660 | <94.07% | 05.93% | 94.07% | 84.19% | 99.21% | 99.97% | 79.19% | 78.54% | 54.39 dBi |
| 36.5° | 0.670 | <93.50% | 06.50% | 93.50% | 84.97% | 99.31% | 99.97% | 79.45% | 78.87% | 54.41 dBi |
| 36.0° | 0.680 | <93.00% | 07.00% | 93.00% | 85.68% | 99.31% | 99.97% | 79.68% | 79.10% | 54.42 dBi |
| 35.5° | 0.690 | <92.46% | 07.54% | 92.46% | 86.31% | 99.31% | 99.97% | 79.80% | 79.22% | 54.43 dBi |
| 35.0° | 0.700 | <91.89% | 08.11% | 91.89% | 86.85% | 99.30% | 99.97% | 79.81% | 79.22% | 54.43 dBi |
| 34.6° | 0.710 | <91.41% | 08.59% | 91.41% | 87.72% | 99.30% | 99.97% | 80.18% | 79.59% | 54.45 dBi |
| 34.1° | 0.720 | <90.77% | 09.23% | 90.77% | 88.09% | 99.30% | 99.96% | 79.97% | 79.37% | 54.44 dBi |

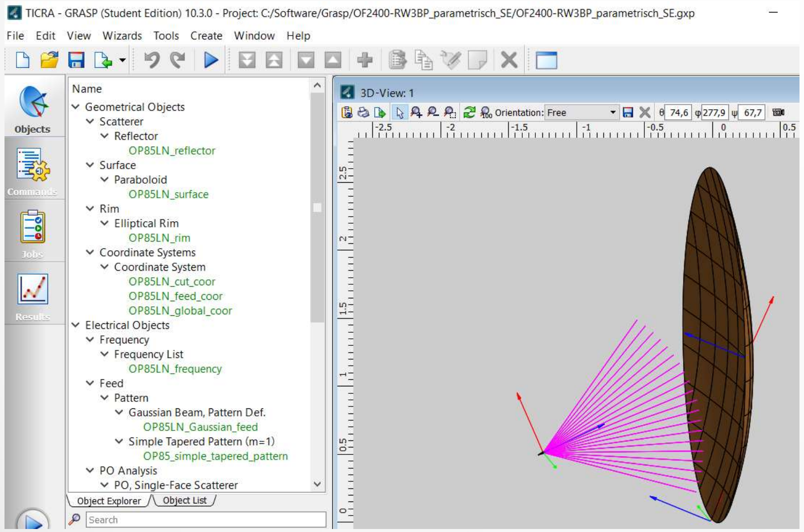
# OFFSET Simulation ist mit OpenEMS möglich, mit GRASP-SE ist es wesentlich einfacher/schneller

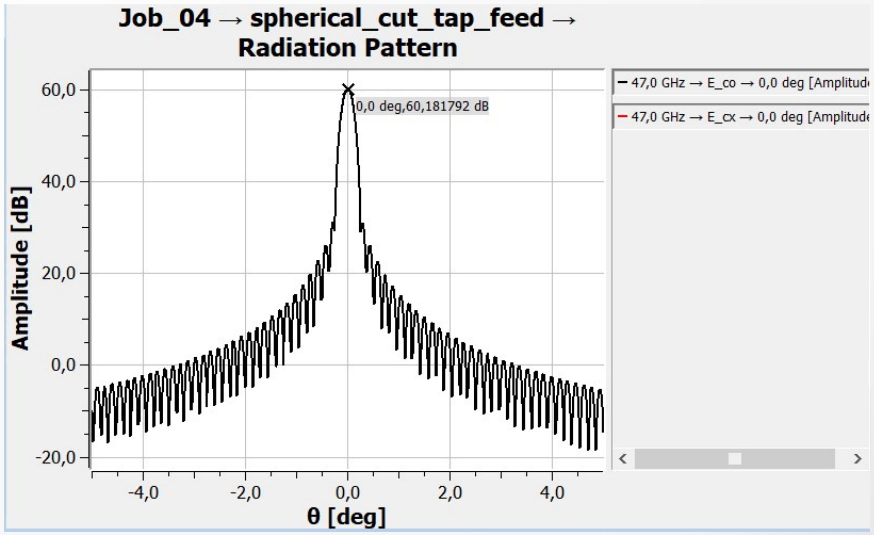
- **OpenEMS:** Strahler + 1.2 m Offsetspiegel, 10 GHz → 32 GB RAM mit 750 Mio. Simulationszellen, Simulationsdauer ~3.5 Stunden



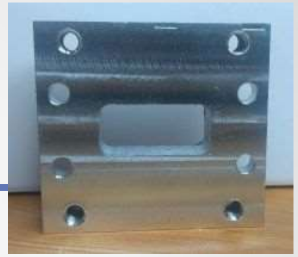



- **GRASP-SE** selbes Ergebnis in max. 5 Minuten für 2.4 m Offset, 47 GHz



# Simulation von λ/4 Anpassplättchen[6]

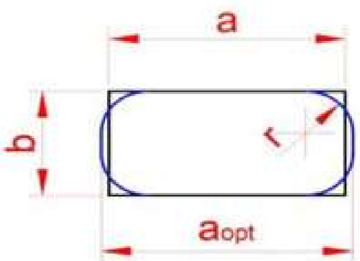


- Dient zur Anpassung von 2 unterschiedlichen Hohlleitern
  - rechteckig – rechteckig
  - rechteckig - rund
- Für schmalbandige Anwendungen völlig ausreichend und schön klein

- Nach zahlreichen Simulationen ist ein Designguide verfügbar, S11 <-25 dB
  PS: Designguide funktioniert auch für 76 GHz (WR12/ø 2.4mm für DC7KY)

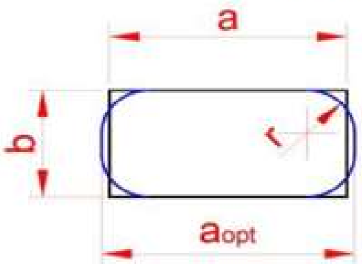
**RESULTS for** **Frequency [GHz] =** **24,048**

| | | | |
|---|---|---|---|
| | | **rect WG 1 ->** | **rect WG 2** |
| **Quarter-Wave adapter plate for :** | | **WR42** | **WR75** |
| max allowed +/- deviation [mm] = | | 0,04 | |
| **rectangular WG with** | **radius r =** | 2,0 | mm |
| | **$a_{opt}$ =** | **13,41** | mm |
| | **b =** | **6,45** | mm |
| | **thickness =** | **3,56** | mm |




$a_{opt}$ by Willi HB9PZK

| | | | |
|---|---|---|---|
| | | **rect WG 1 ->** | **circ WG 1** |
| **Quarter-Wave adapter plate for :** | | **WR42** | **13,4 mm** |
| max allowed +/- deviation [mm] = | | 0,08 | |
| **rectangular WG with** | **radius r =** | 2,0 | mm |
| | **$a_{opt}$ =** | **11,44** | mm |
| | **b =** | **7,36** | mm |
| | **thickness =** | **3,13** | mm |




$a_{opt}$ by Willi HB9PZK

# Wissenswertes zum Mitnehmen

- Mit **GRASP-SE** und/oder **OpenEMS** kann jeder **kostenlos** Strahler & Spiegel Simulationen durchführen

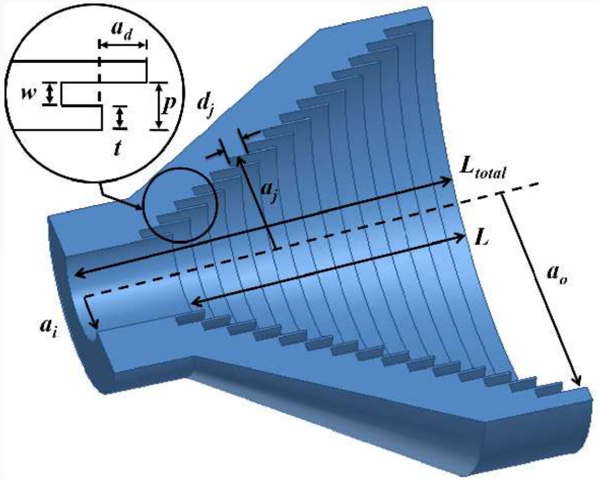
- Mit OpenEMS mehr Grundwissen nötig und ...
→ Lernkurve ist langsamer
→ es stehen aber viele fertige Simulationsbeispiele zur Verfügung
→ man kann viel flexibler agieren

- Die **Genauigkeit** der kostenlosen Tools kann mit den Vollversionen der Profitools (GRASP, CST, HSFF, ...) mithalten

- Ergebnisse lassen sich sehr gut in meinem „EME Link Budet & Analysis Tool“ verwenden
https://wettersat.bplaced.net/EME/EME.html

# … und es geht 2025 weiter

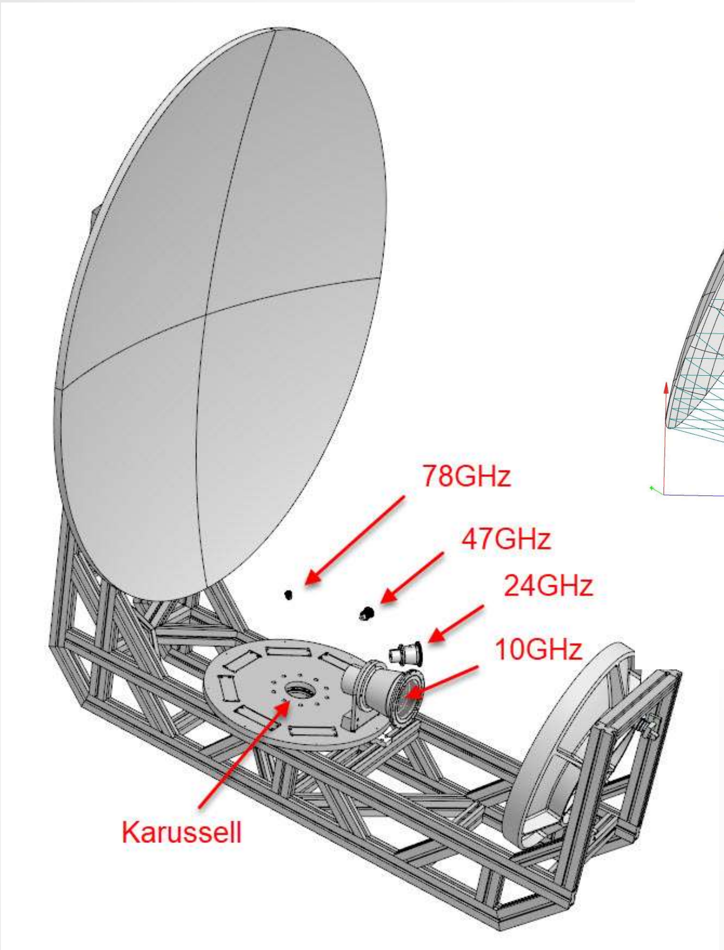
- Simulation von Rillenhornstrahlern für **f/D = 0.3 – 0.8**
  **Ziel:** Wirkungsgrad > 82% mit sehr geringen Seitenkeulen

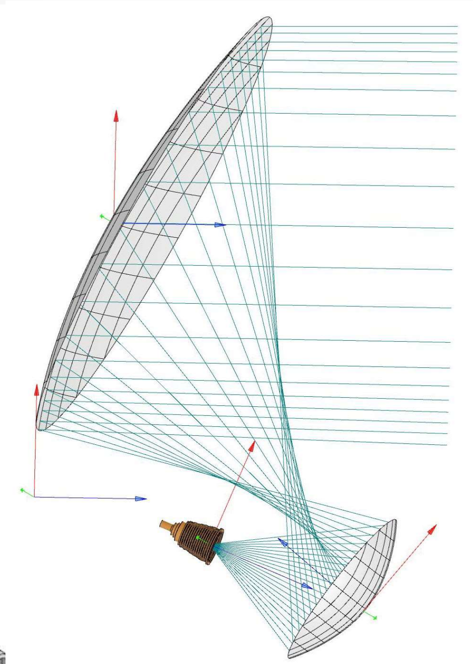


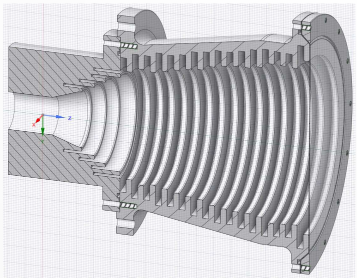

- Um den **realen Gewinn** zu bestimmen, soll Strahler/Spiegel über die Seitenkeulen mittels einer Bake oder QO-100 vermessen werden.

# … Zugabe für unsere Profis

**© Willi Göldi[8] , HB9PZK**





**1.3m Gregory Dual-Offset System:**
10 GHz: ~89% Wirkungsgrad
47 GHz: ~93% Wirkungsgrad
76 GHz: ~93% Wirkungsgrad

(*) funktioniert nur über „shaped reflector“

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# Danke für eure Aufmerksamkeit

**Spezieller Dank gebührt** Willi Göldi HB9PZK, Luis Cupido CT1DMK und Erich OE9ERC für die zahlreichen Diskussionen.

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