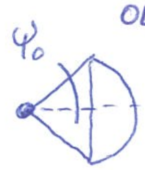
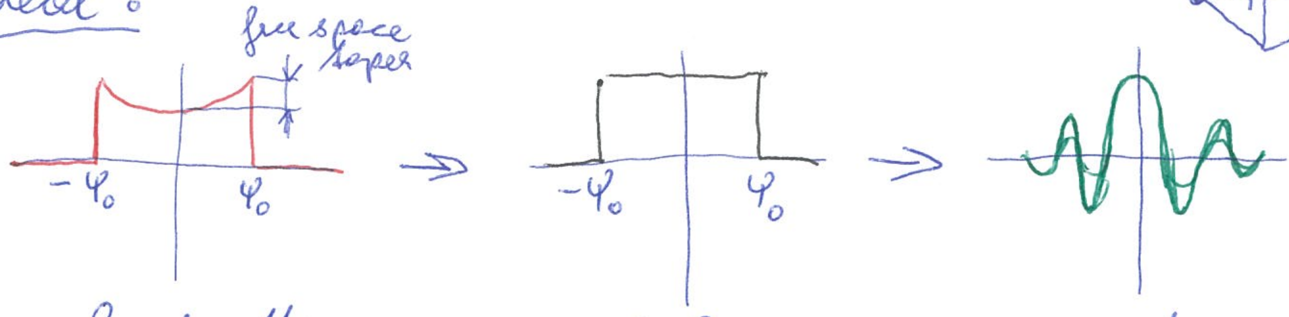
V2 21.8.2023 OE2IGL

Dish illumination, feed shape



Ideal:



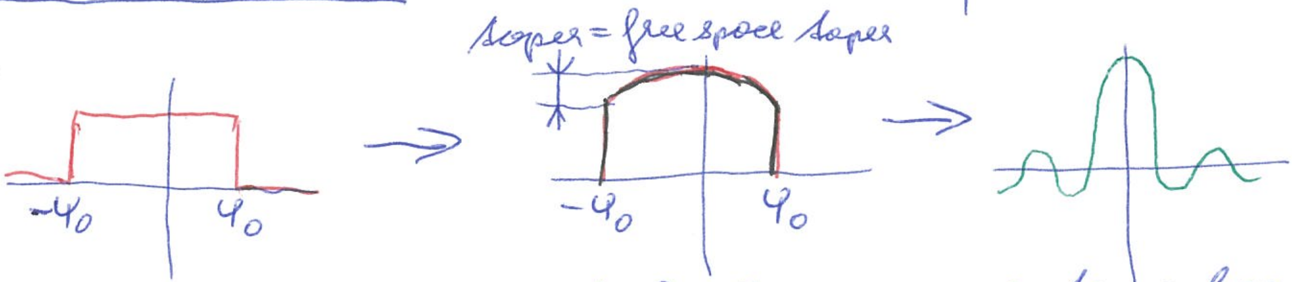
feed pattern — dish illumination — antenna beam

$$\Theta^{\circ}_{-3db} = b_{(T)} \cdot \frac{180}{\pi} \cdot \frac{\lambda}{d} \qquad b_{(0db)} = 1{,}029$$

$$\Rightarrow \boxed{G = \underbrace{20 \log \frac{\pi d}{\lambda}}_{\text{gain uniform illum.}} + 10 \log \underbrace{\left(\frac{\cancel{1{,}029}}{\cancel{b(0)}}\right)^2}_{\eta_{Aper} = \eta_i \cdot \eta_s} = 20 \log \frac{\pi d}{\lambda}}$$

$\Rightarrow$ Ideal, if feed pattern is uniform illumination, max. possible gain with $\eta_{aper} = 100\%$ ($= \eta_i$), $\eta_s = 100\%$.

Almost ideal: non-uniform rectangular or quadratic shape



feed pattern — dish illum. — antenna beam

$\Rightarrow b_{(T)} = b(T(f/D))$

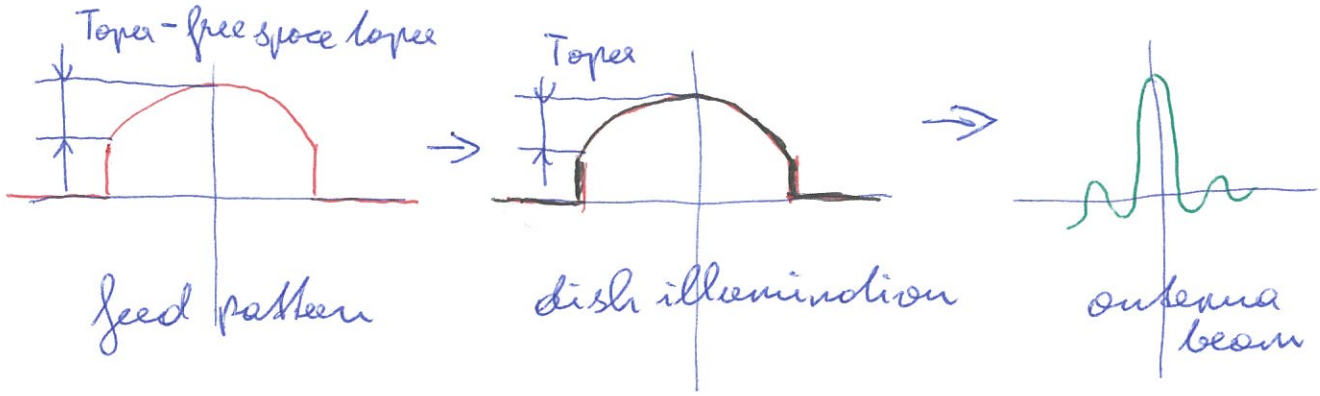
2b: $f/D = 0{,}4 \rightarrow T \approx 2{,}0$ db $\rightarrow b \approx 1{,}061 = \eta_i = 94\%$

$$\Rightarrow G = 20 \log \frac{\pi d}{\lambda} + 10 \log \left(\frac{1{,}029}{1{,}061}\right)^2 = G_{max} + 10 \log \eta_{aper}$$

$\boxed{G = G_{max} + 10 \log \eta_i}$ ($\eta_s = 100\%$)

reality theoretical: approximation of ideal feed for best η_{taper} $(= \eta_i \cdot \eta_s)$

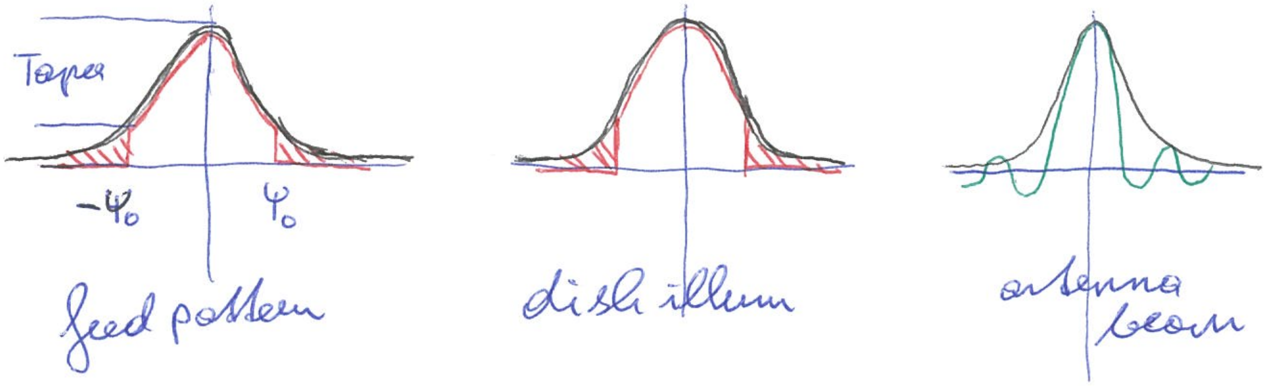
* quadratic + pedestal (Bessel function needed)



best η_{taper} for $T \approx -11$ db

$\Rightarrow b_{(-11)} \approx 1,147 \Rightarrow \eta_{taper\,max} = \left(\frac{1,029}{1,147}\right)^2 \approx 81\%$

* gaussian distribution



$T = \infty \Rightarrow$ gaussian feed pattern $\Rightarrow$ gaussian dish illum.
$\Rightarrow$ gaussian antenna beam

$T < \infty \Rightarrow$ for gaussian feed pattern flanks are cut off. resulting in an antenna beam like green curve

$\Rightarrow b(-11) \approx 1,147 \Rightarrow \eta_{taper\,max} = \left(\frac{1,029}{1,147}\right)^2 \approx 81\% = \eta_i \cdot \eta_s$

Now $\eta_s < 100\%$!

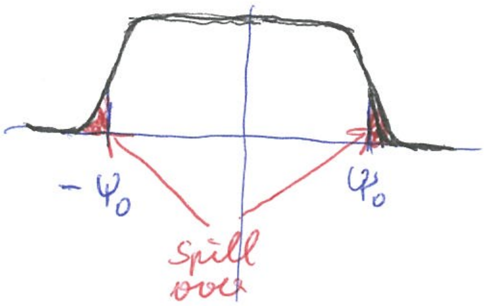
reality:

real pattern isn't quadratic or gauss (or cos ..).
To know exact η_{aper} we have to measure the feed pattern and make a numerically calculation.
Joachim DF3GJ has written a tool to get η_{aper} depending on measured or calculated feed pattern.
(or tool by W1GHz)

$\Rightarrow$ $\eta_{aper} < 81\% = (\eta_i \cdot \eta_s)$

empirical values are up to -10db below.

for a good feed you need
- a top hat with flanks at $-\varphi_0, +\varphi_0$
- very steep flanks



Illumination efficiency

exact form:

$$\eta_i = \frac{2}{\tan^2\left(\frac{\psi_0}{2}\right)} \cdot \frac{\left|\int_0^{\psi_0} \left(|E_E| + |E_H|\right) \tan\left(\frac{\psi}{2}\right) d\psi\right|^2}{\int_0^{\psi_0} \left(|E_E| + |E_H|\right)^2 \sin(\psi)\, d\psi}$$

E ... electrical field in E and H direction

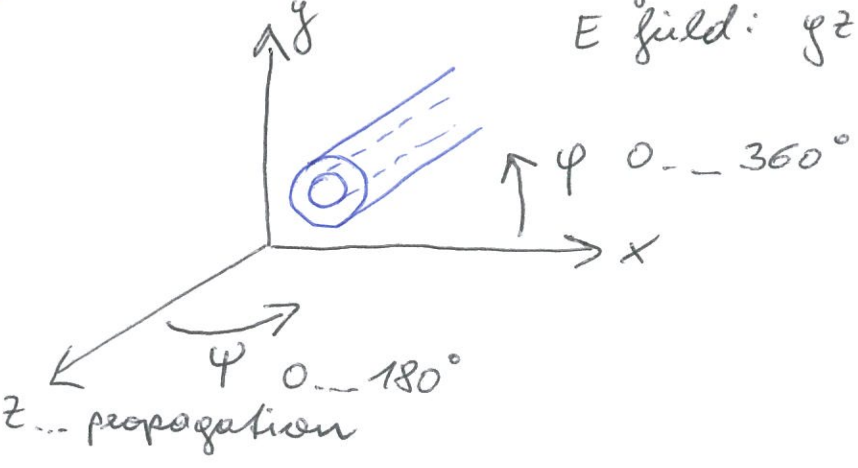
Spillover efficiency

exact form:

$$\eta_S = \frac{\int_0^{\psi_0} \left(|E_E|^2 + |E_H|^2\right) \sin(\psi)\, d\psi}{\int_0^{\pi} \left(|E_E|^2 + |E_H|^2\right) \sin(\psi)\, d\psi}$$

coordinates:

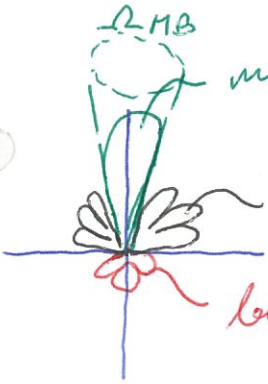
H field: xz-plane
E field: yz-plane



Some definitions about antenna pattern

$$\Omega_A = \int_{4\pi} P(\Omega)\, d\Omega \qquad \Omega_{MB} = \int_{MB} P(\Omega)\, d\Omega$$

$$\Omega_F = \int_{2\pi} P(\Omega)\, d\Omega$$



main beam, η_{MB}

side lobes, $(\eta_F - \eta_{MB})$

back lobes, $(1-\eta_F)$

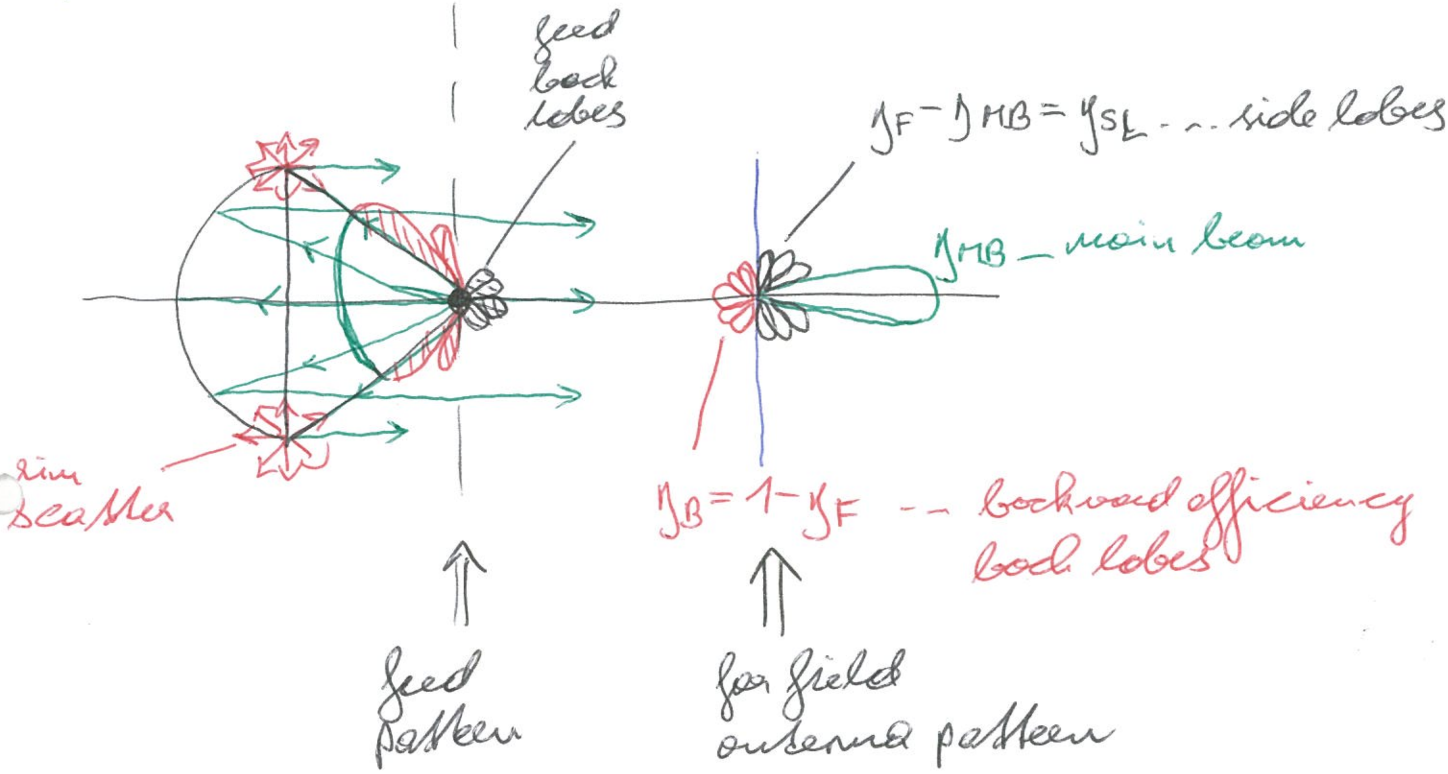
main beam efficiency: $\eta_{MB} = \dfrac{\Omega_{MB}}{\Omega_A}$

forward efficiency: $\eta_F = \dfrac{\Omega_F}{\Omega_A}$

feed efficiency: $\eta_{feed} = \dfrac{\Omega_{Feed,R}}{\Omega_{A,feed}} = \dfrac{\int_{\Omega_R} P(\Omega)_{feed} \cdot d\Omega}{\Omega_{A,feed}}$

From feed pattern to dish pattern

Approximation without using simulation of rays.



- feed spillover pattern ( ) results in back + side + noise in η_{MB} of antenna pattern.
- feed pattern which illuminates the dish results in main beam of antenna and additional side lobes + back lobes because of rim scatter

- $\eta_{B,ant} = 1 - \eta_{F,ant} =$

$$\eta_{B,ant} = Loss|_{spillover} + 50\% \, Loss|_{scatter\,rim} - Loss|_{B\,feed} =$$

$$\Rightarrow (1 - \eta_{spillover}) + 50\% \, Loss|_{scatter\,rim} - Loss|_{B\,Feed} = 1 - \eta_{F,ant}$$

$$\eta_{F,ant} = \eta_{spillover} - 50\% \, Loss|_{scatter\,rim} + Loss|_{B\,Feed}$$

$$\eta = 10^{\frac{Loss_{dB}}{10}}$$

$$Loss_{rim} = 1 - \eta$$