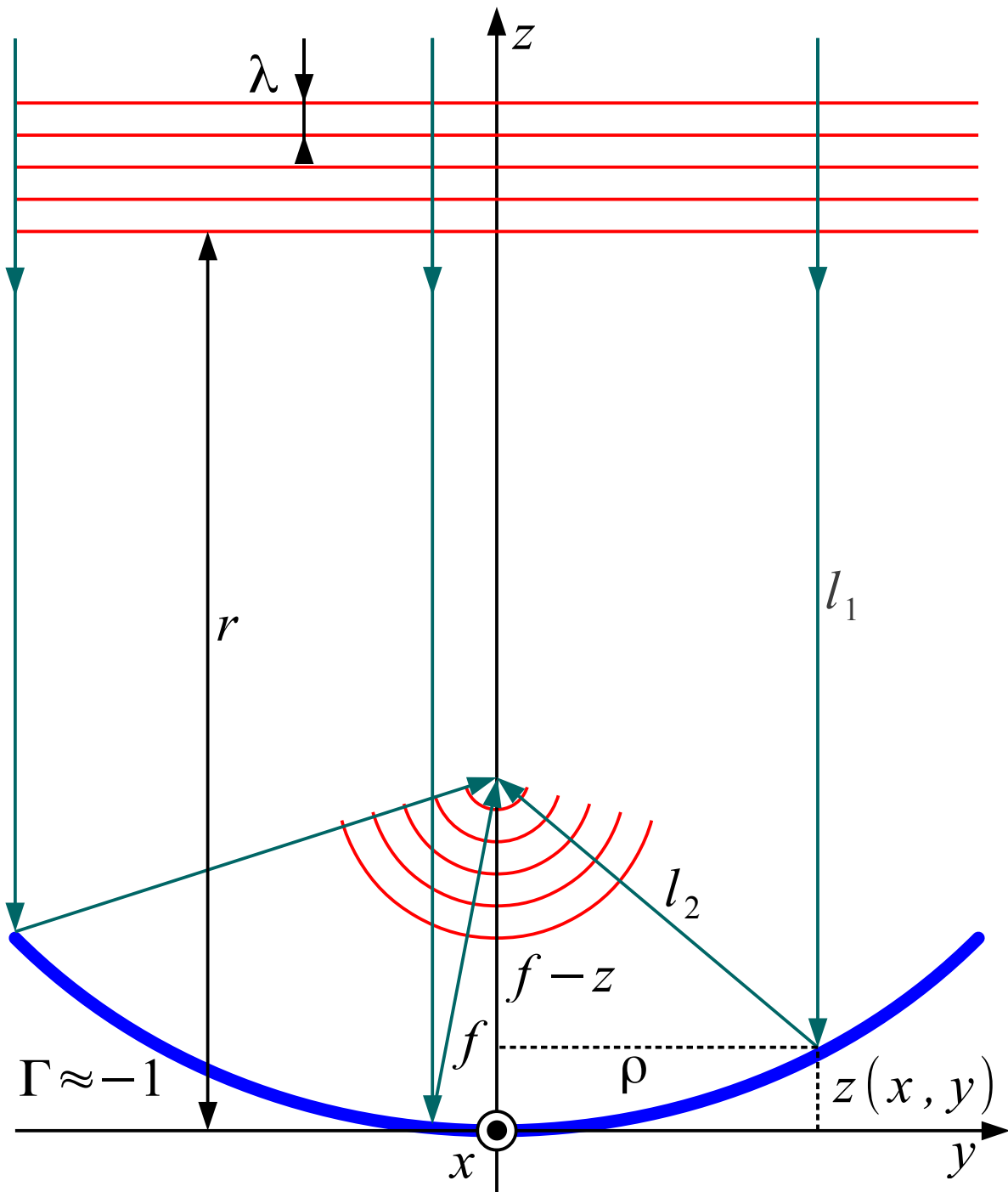


Zrcalo



$$l_1 + l_2 = \text{konst.} = r + f$$

$$l_1 = r - z$$

$$l_2 = \sqrt{(f - z)^2 + \rho^2}$$

$f \equiv$ goriščna razdalja

$$r - z + \sqrt{(f - z)^2 + \rho^2} = r + f$$

$$\sqrt{(f - z)^2 + \rho^2} = f + z$$

$$(f - z)^2 + \rho^2 = (f + z)^2$$

$$f^2 - 2fz + z^2 + \rho^2 = f^2 + 2fz + z^2$$

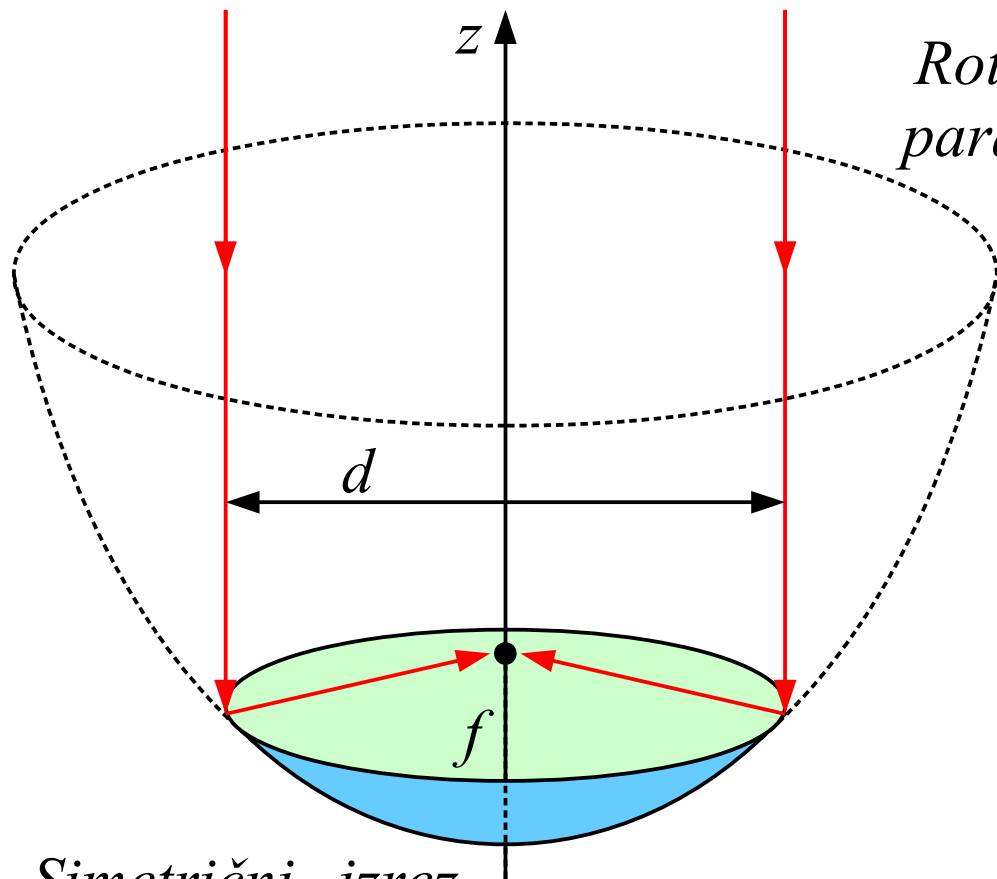
$$\rho = \sqrt{x^2 + y^2}$$

$$\rho^2 = 4fz = x^2 + y^2$$

Rotacijski paraboloid:

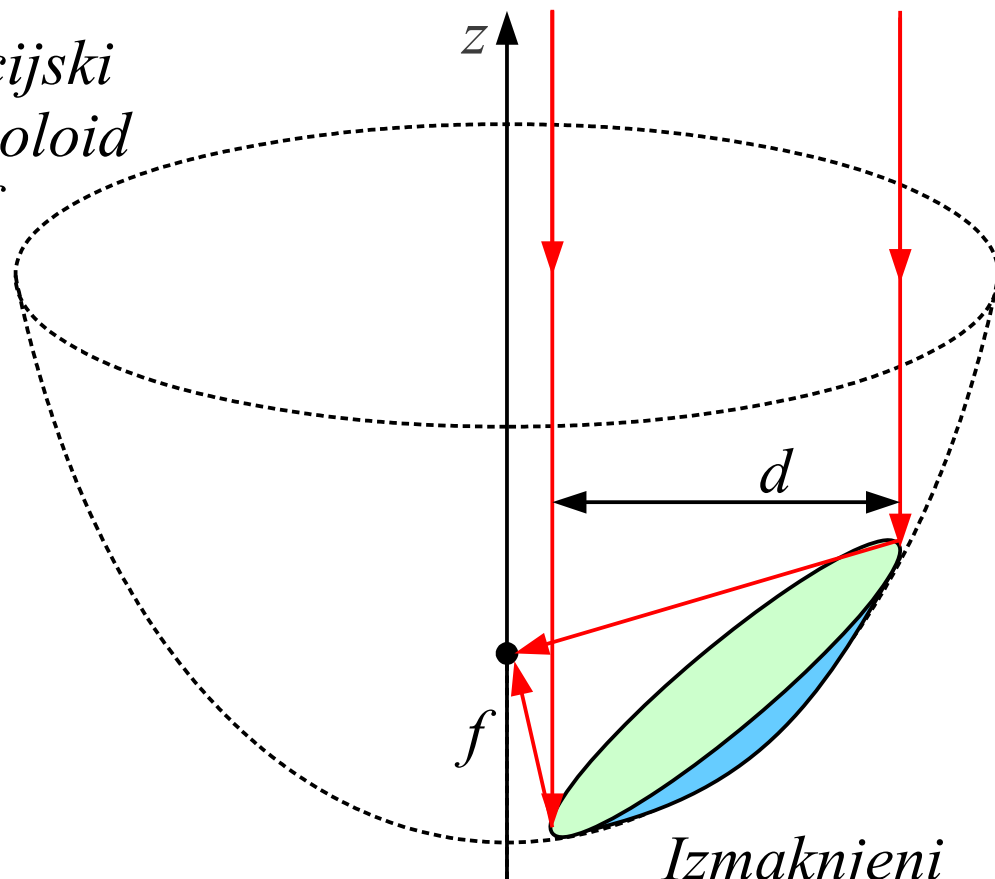
$$z(x, y) = \frac{x^2 + y^2}{4f}$$

Zbiralno zrcalo

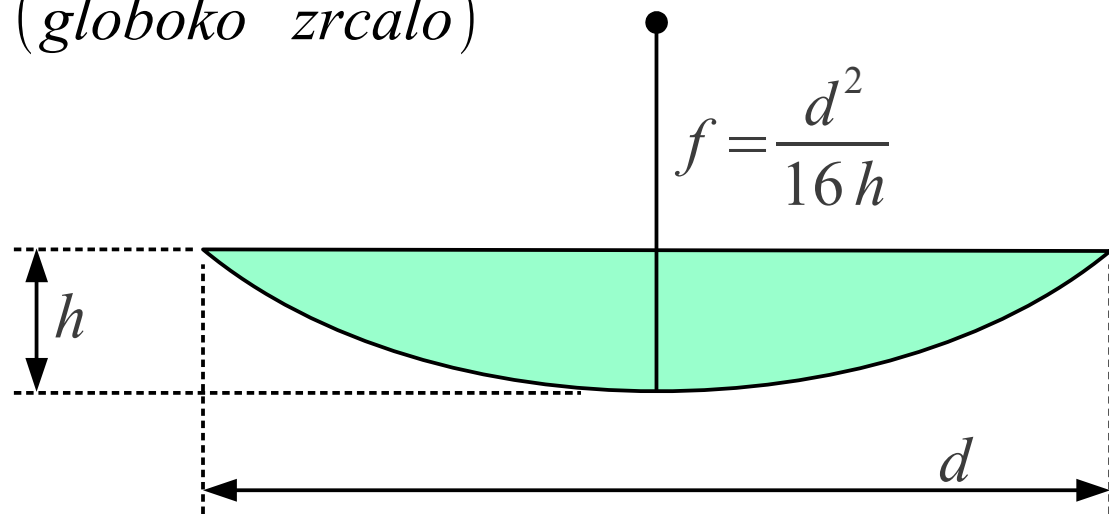


*Rotacijski
paraboloid*
 f

Simetrični izrez
 $f/d \approx 0.3 \dots 0.4$
(globoko zrcalo)



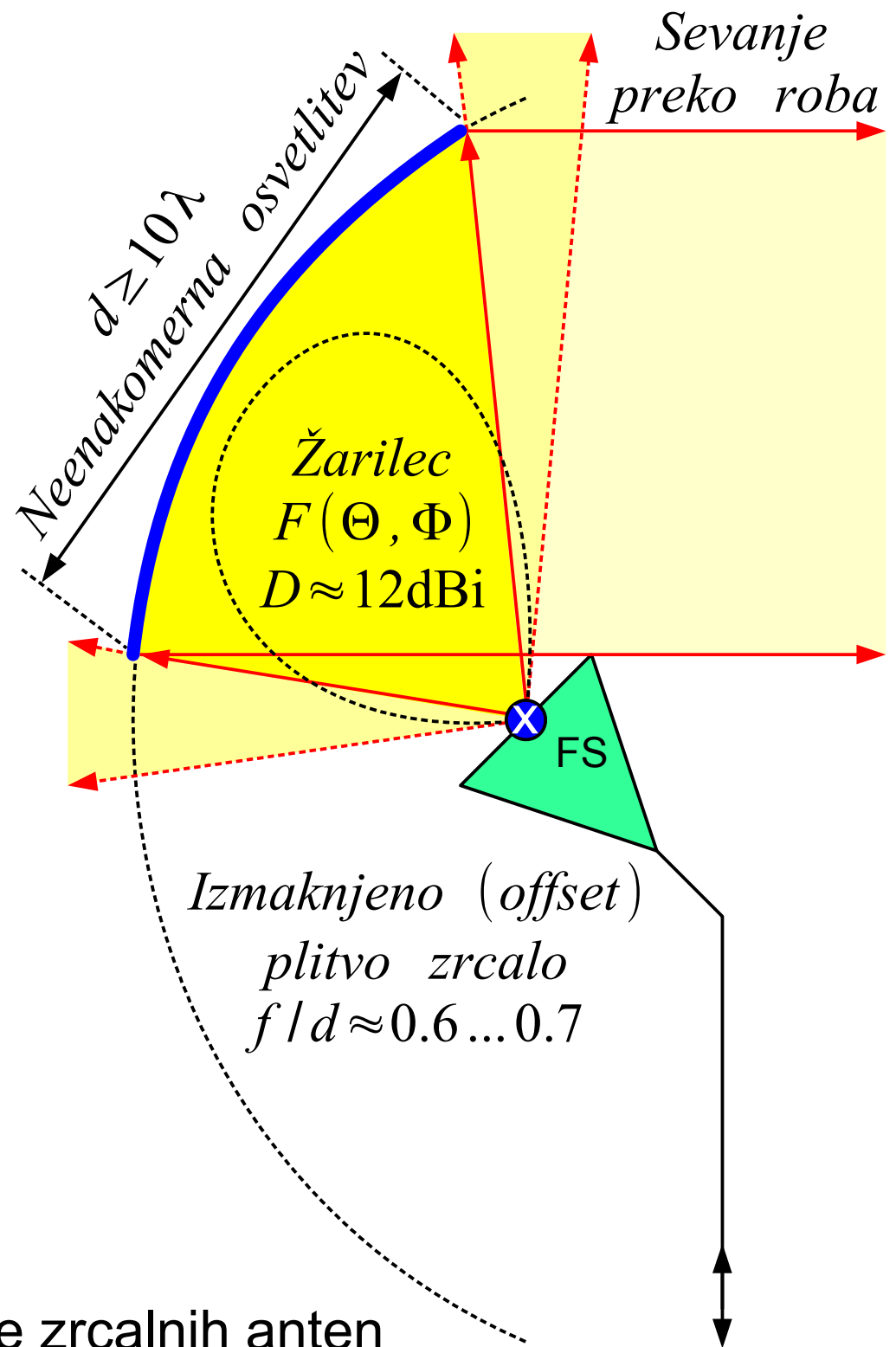
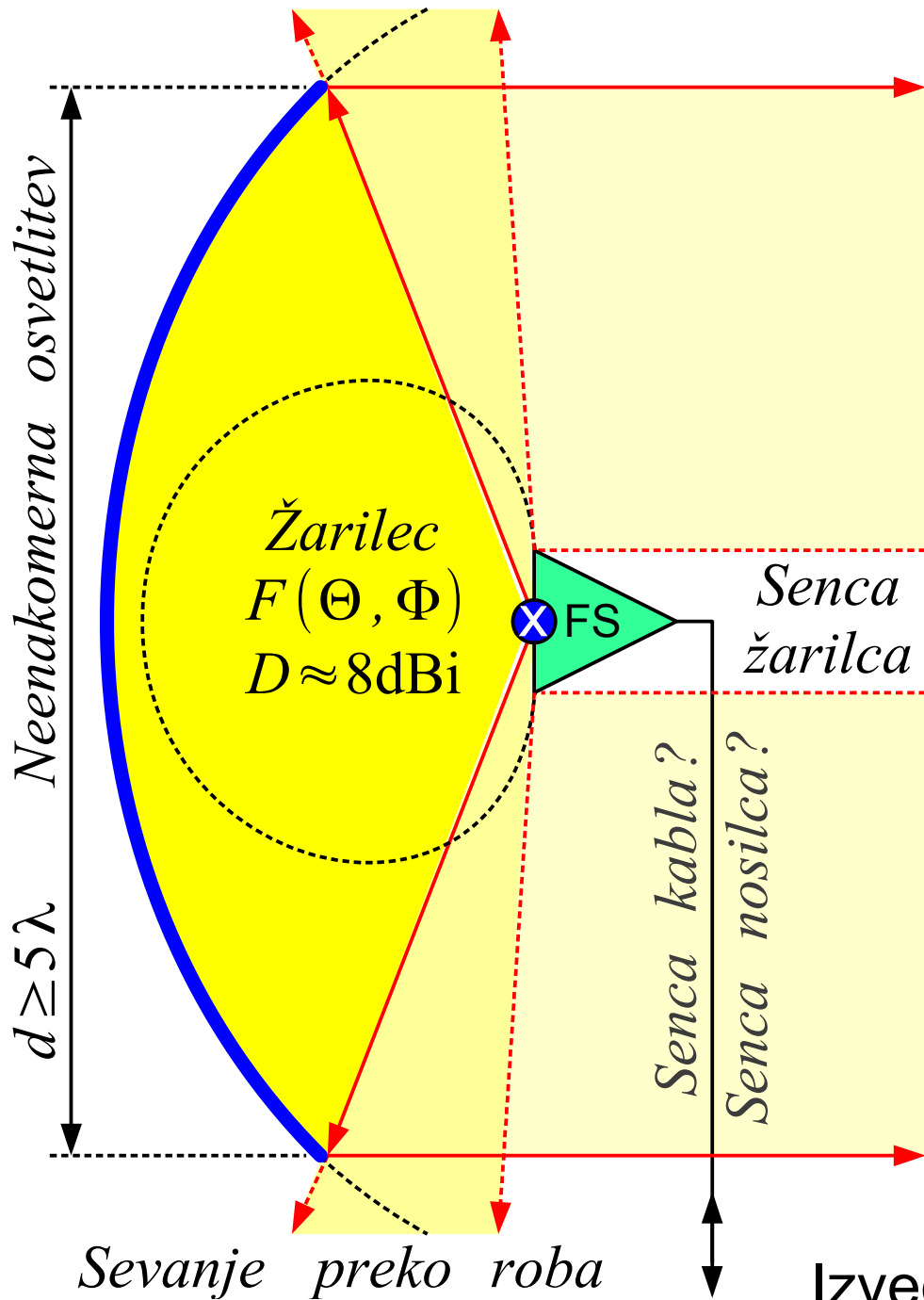
*Izmaknjeni
(offset) izrez*
 $f/d \approx 0.6 \dots 0.7$
(plitvo zrcalo)



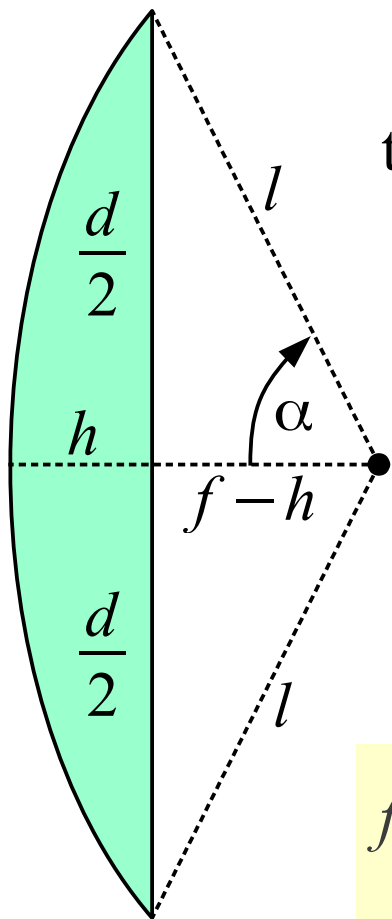
Fotoaparat
 $f/d \approx 1.8 \dots 22$

Izrezi zrcala

Rotacijsko – simetrično globoko
zrcalo $f/d \approx 0.3 \dots 0.4$



Izvedbe zrcalnih anten



$$\tan \alpha = \frac{\frac{d}{2}}{f-h} = \frac{\frac{d}{2}}{f - \frac{d^2}{16f}} = \frac{2 \cdot \frac{d}{4f}}{1 - \left(\frac{d}{4f}\right)^2}$$

$$h = \frac{d^2}{16f}$$

$$\tan \frac{\alpha}{2} = \frac{d}{4f}$$

$$\tan \alpha = \frac{2 \tan \frac{\alpha}{2}}{1 - \left(\tan \frac{\alpha}{2}\right)^2}$$

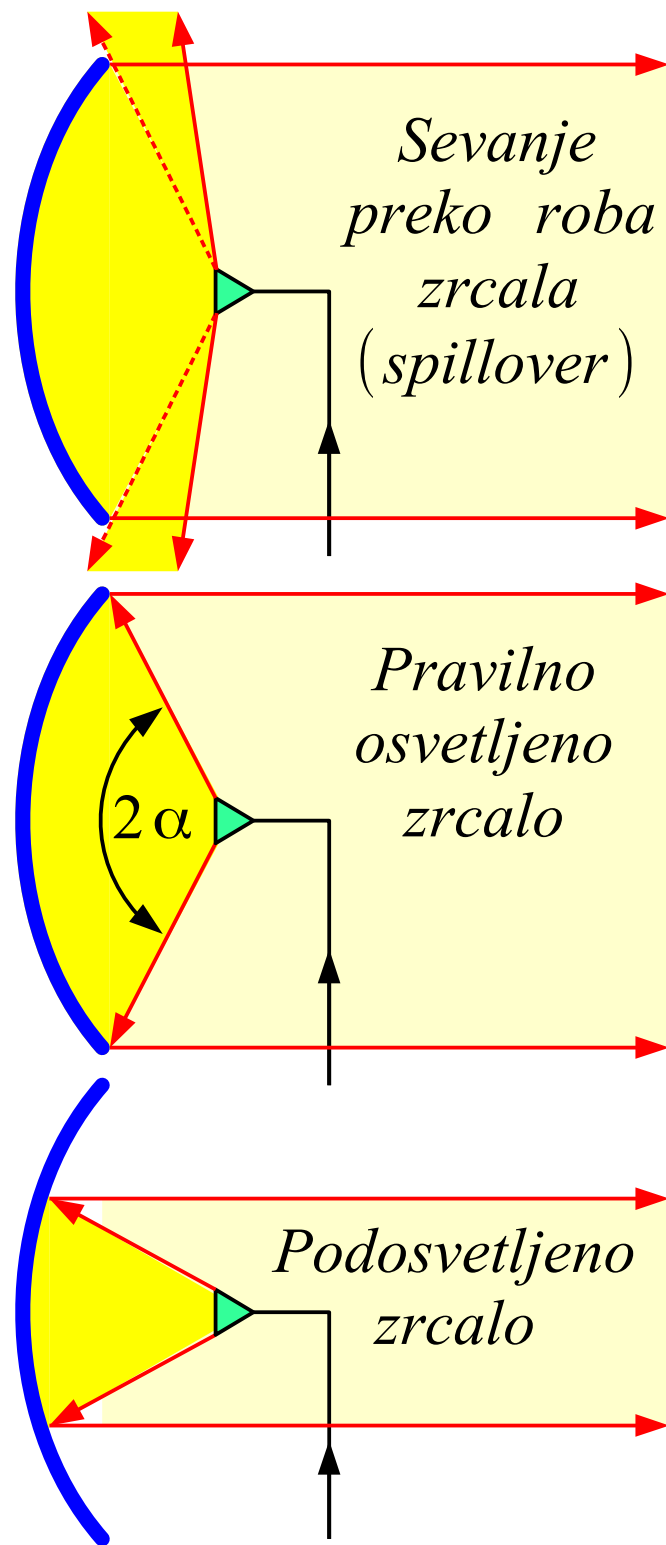
$$f/d = \frac{1}{4 \tan \frac{\alpha}{2}}$$

$$\alpha = 2 \arctan \frac{1}{4(f/d)}$$

$$l = \sqrt{(d/2)^2 + (f-h)^2} = f \left[1 + \left(\frac{1}{4(f/d)} \right)^2 \right]$$

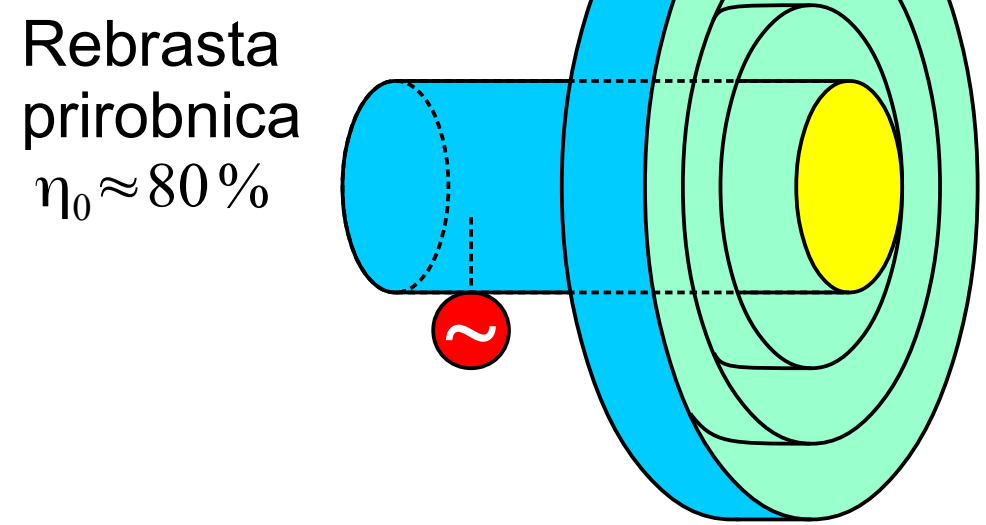
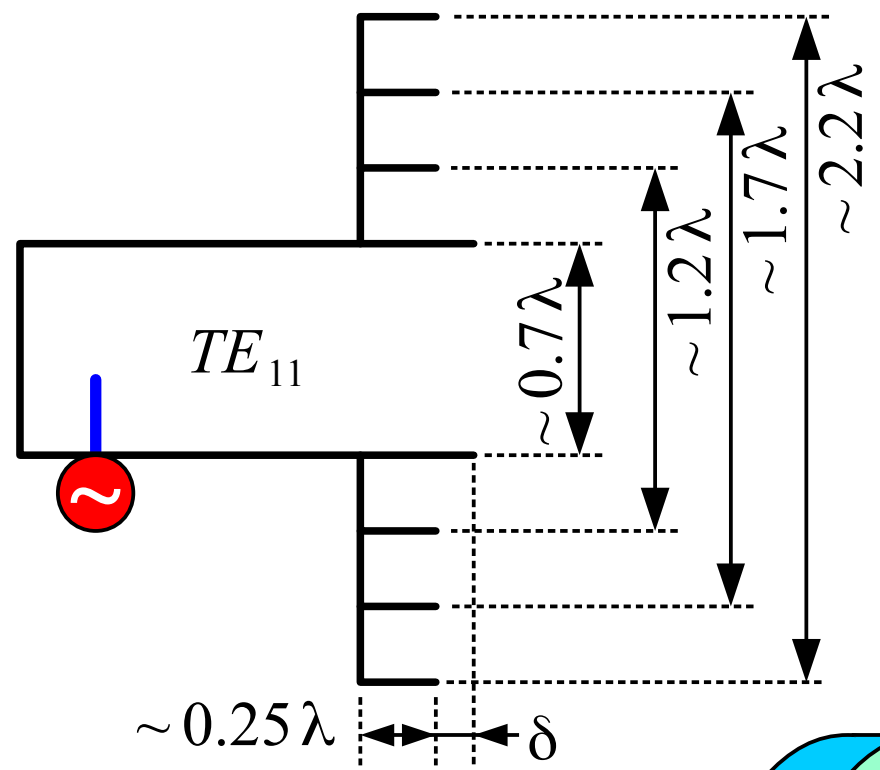
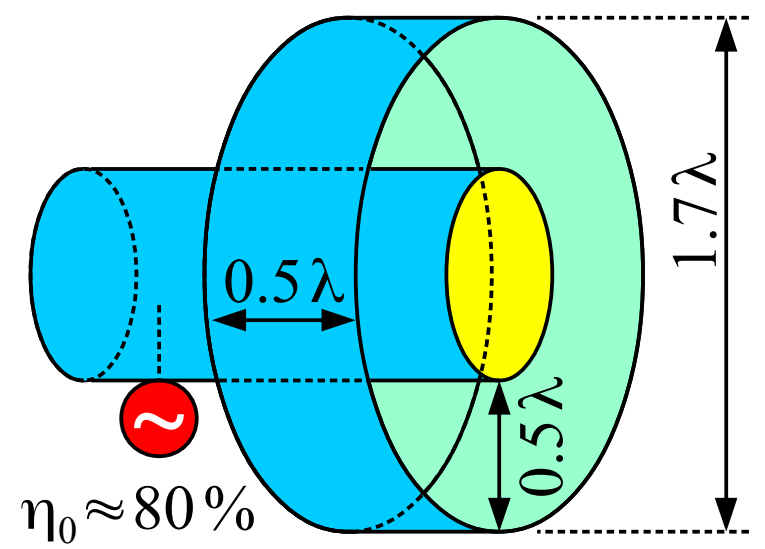
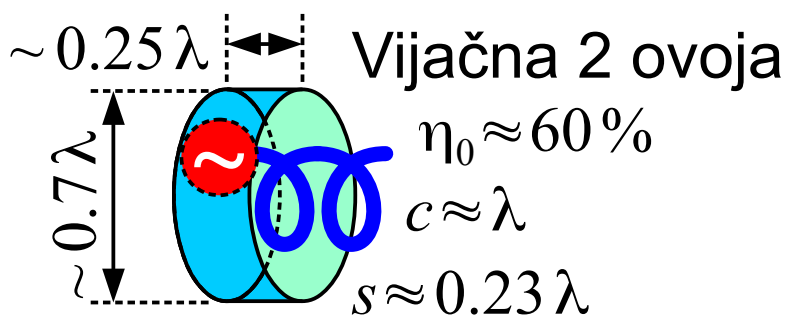
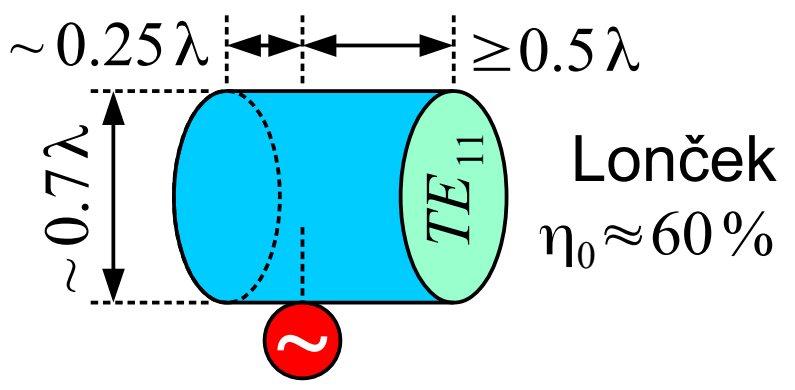
Zgled $f/d = 0.4 \rightarrow \alpha \approx 1.12 \text{rd} \approx 64^\circ \quad 2\alpha \approx 128^\circ$

$l \approx 1.39f \rightarrow 20 \log_{10}(l/f) \approx 2.86 \text{dB}$



Osvetlitev zrcala

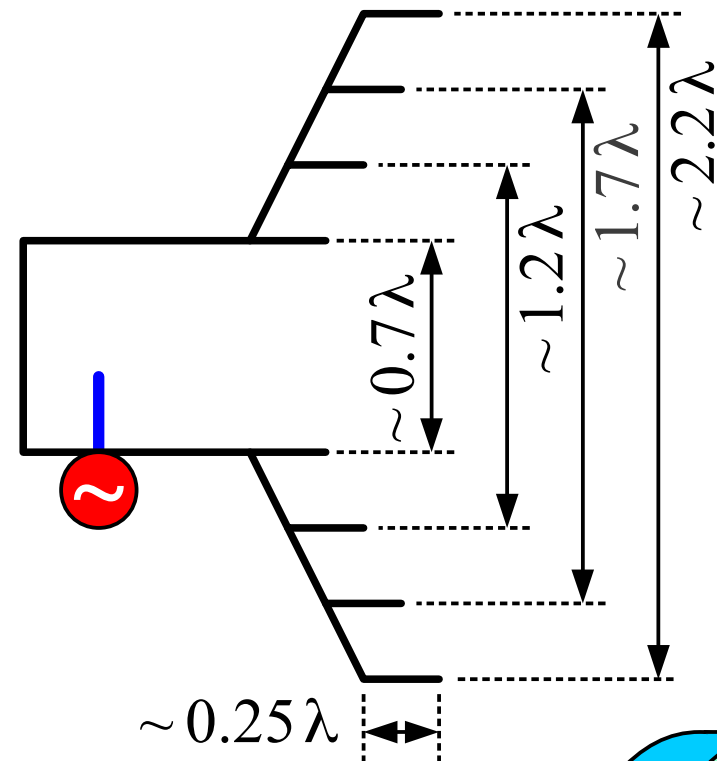
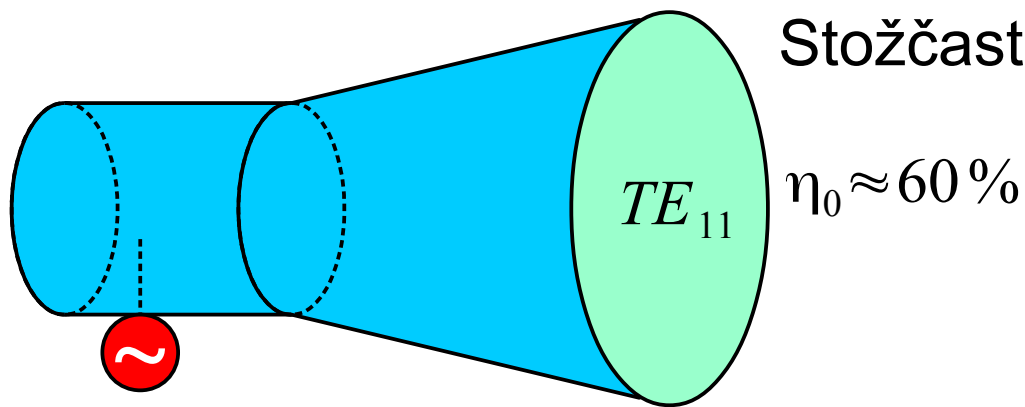
Žarilci za globoka zrcala



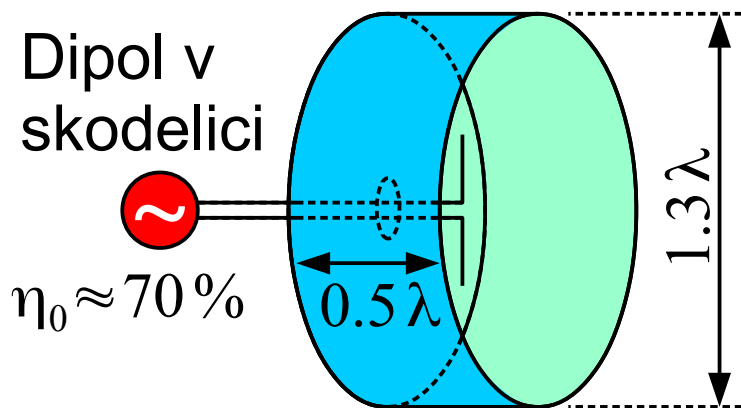
Ovratnik Kumar/VE4MA

Stožčasti lijak

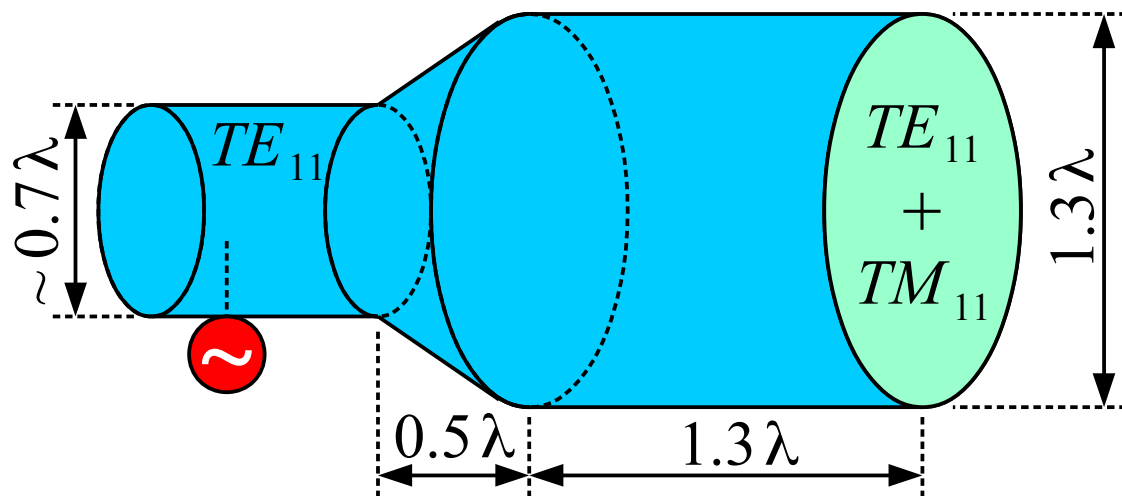
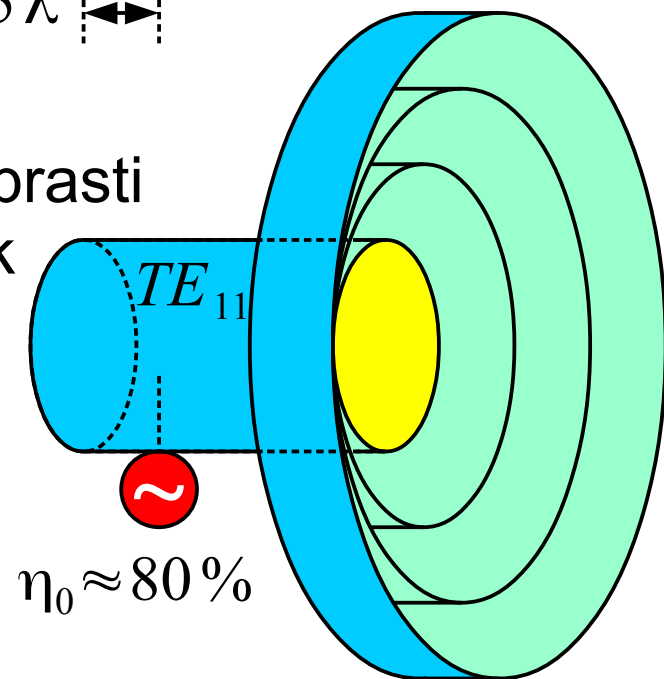
Žarilci za plitva zrcala



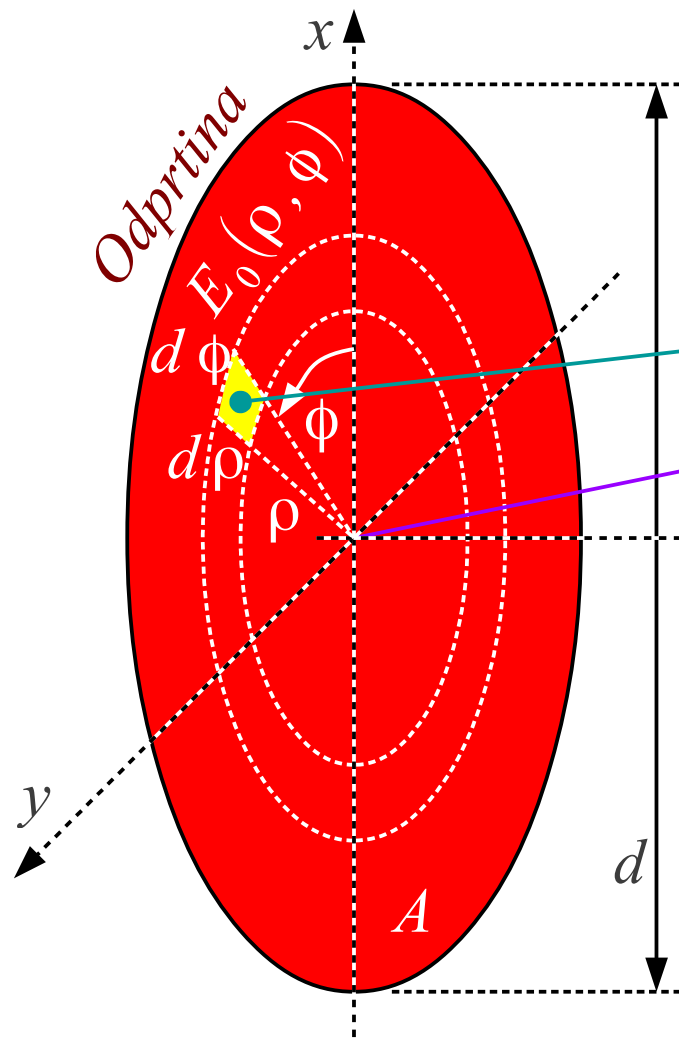
Dipol v skodelici



Rebrasti lijak



Dvorodovni žarilec $\eta_0 \approx 80\%$



Daljnje polje $r > \frac{2d^2}{\lambda}$

$$\vec{E}(r, \Theta, \Phi)$$

$$\vec{r} - \vec{r}'$$

$$\vec{r}$$

$$\Theta$$

$$dE \approx \frac{j}{2\lambda} E_0(\rho, \phi) \rho d\rho d\phi \frac{e^{-jk|\vec{r}-\vec{r}'|}}{|\vec{r}-\vec{r}'|} (1 + \cos \Theta)$$

$$\vec{r}' = \vec{1}_x \rho \cos \phi + \vec{1}_y \rho \sin \phi$$

$$|\vec{r} - \vec{r}'| = \sqrt{(x - \rho \cos \phi)^2 + (y - \rho \sin \phi)^2 + z^2}$$

$$\text{Faza } k|\vec{r} - \vec{r}'| \approx k(r - \rho \sin \Theta \cos(\Phi - \phi))$$

$$dE \approx \frac{j}{2\lambda} E_0(\rho, \phi) \rho d\rho d\phi \frac{e^{-jkr}}{r} (1 + \cos \Theta) e^{jk\rho \sin \Theta \cos(\Phi - \phi)}$$

$$E = E(r, \Theta, \Phi) = \iint_A dE \approx \frac{j}{2\lambda} \frac{e^{-jkr}}{r} (1 + \cos \Theta) \int_0^{d/2} \int_0^{2\pi} E_0(\rho, \phi) e^{jk\rho \sin \Theta \cos(\Phi - \phi)} \rho d\rho d\phi$$

Sevanje krožne odprtine

$$E_0(\rho, \phi) = \text{konst.} = C$$

$$J_n(t) = \sum_{m=0}^{\infty} \frac{(-1)^m t^{2m+n}}{2^{2m+n} m! (m+n)!}$$

$$E = \frac{j}{2\lambda} C \frac{e^{-jkr}}{r} (1 + \cos \Theta) \int_0^{d/2} \int_0^{2\pi} e^{jk\rho \sin \Theta \cos(\Phi - \phi)} \rho d\rho d\phi$$

$$\int_0^{2\pi} e^{jt \cos \phi} d\phi = 2\pi J_0(t)$$

$$E = \frac{j}{\lambda} C \frac{e^{-jkr}}{r} \frac{1 + \cos \Theta}{2} \int_0^{d/2} 2\pi J_0(k\rho \sin \Theta) \rho d\rho$$

$$\frac{d}{dt} [t^n J_n(t)] = t^n J_{n-1}(t)$$

$$\int_0^{d/2} 2\pi J_0(k\rho \sin \Theta) \rho d\rho = 2\pi \left[\rho \frac{J_1(k\rho \sin \Theta)}{k \sin \Theta} \right]_0^{d/2} = \pi \left(\frac{d}{2} \right)^2 \frac{2 J_1\left(\frac{kd}{2} \sin \Theta\right)}{\frac{kd}{2} \sin \Theta}$$

$$A = \pi \left(\frac{d}{2} \right)^2$$

$$\frac{kd}{2} = \frac{\pi d}{\lambda}$$

$$F(\Theta, \Phi) = \frac{1 + \cos \Theta}{2} \frac{2 J_1\left(\frac{\pi d}{\lambda} \sin \Theta\right)}{\frac{\pi d}{\lambda} \sin \Theta}$$

$$E = \frac{j}{\lambda} C A \frac{e^{-jkr}}{r} \frac{1 + \cos \Theta}{2} \frac{2 J_1\left(\frac{kd}{2} \sin \Theta\right)}{\frac{kd}{2} \sin \Theta}$$

$$J_1(t) = 0 \rightarrow t \approx 3.8318$$

Enakomerno osvetljen krog

$$\alpha_{-3\text{dB}} \approx \Theta_0 \approx \arcsin \Theta_0 \approx \frac{3.8318\lambda}{\pi d} \approx 1.22 \frac{\lambda}{d}$$

$$E_0(\rho, \phi) = C e^{-j\Delta\phi(2\rho/d)^2}$$

$$\int_0^{2\pi} e^{jt \cos\phi} d\phi = 2\pi J_0(t)$$

$$E = \frac{j}{2\lambda} \frac{e^{-jkr}}{r} (1 + \cos\Theta) \int_0^{d/2} \int_0^{2\pi} C e^{-j\Delta\phi(2\rho/d)^2} e^{jk\rho \sin\Theta \cos(\Phi-\phi)} \rho d\rho d\phi$$

$$E = \frac{j}{\lambda} \frac{e^{-jkr}}{r} \frac{1 + \cos\Theta}{2} \int_0^{d/2} C e^{-j\Delta\phi(2\rho/d)^2} 2\pi J_0(k\rho \sin\Theta) \rho d\rho$$

$$A = \pi \left(\frac{d}{2}\right)^2$$

$$E = \frac{j}{\lambda} C A \frac{e^{-jkr}}{r} \frac{1 + \cos\Theta}{2} \left[\frac{8}{d^2} \int_0^{d/2} e^{-j\Delta\phi(2\rho/d)^2} J_0(k\rho \sin\Theta) \rho d\rho \right]$$

$$F(\Theta, \Phi) = \frac{1 + \cos\Theta}{2} \left[\frac{8}{d^2} \int_0^{d/2} e^{-j\Delta\phi(2\rho/d)^2} J_0(k\rho \sin\Theta) \rho d\rho \right]$$

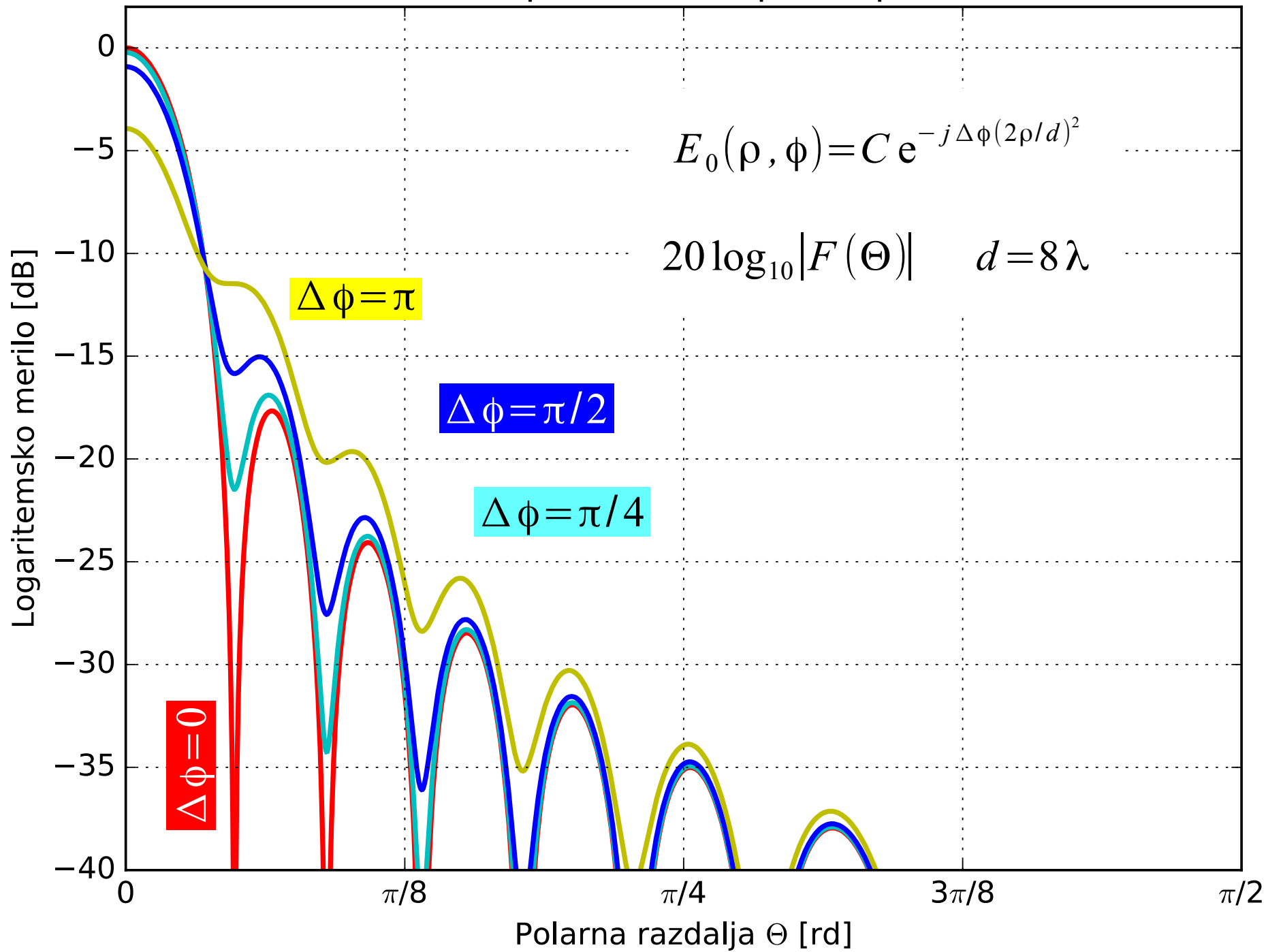
$$\Theta = 0 \rightarrow \cos\Theta = 1 \quad J_0(k\rho \sin\Theta) = 1 \quad u = (2\rho/d)^2$$

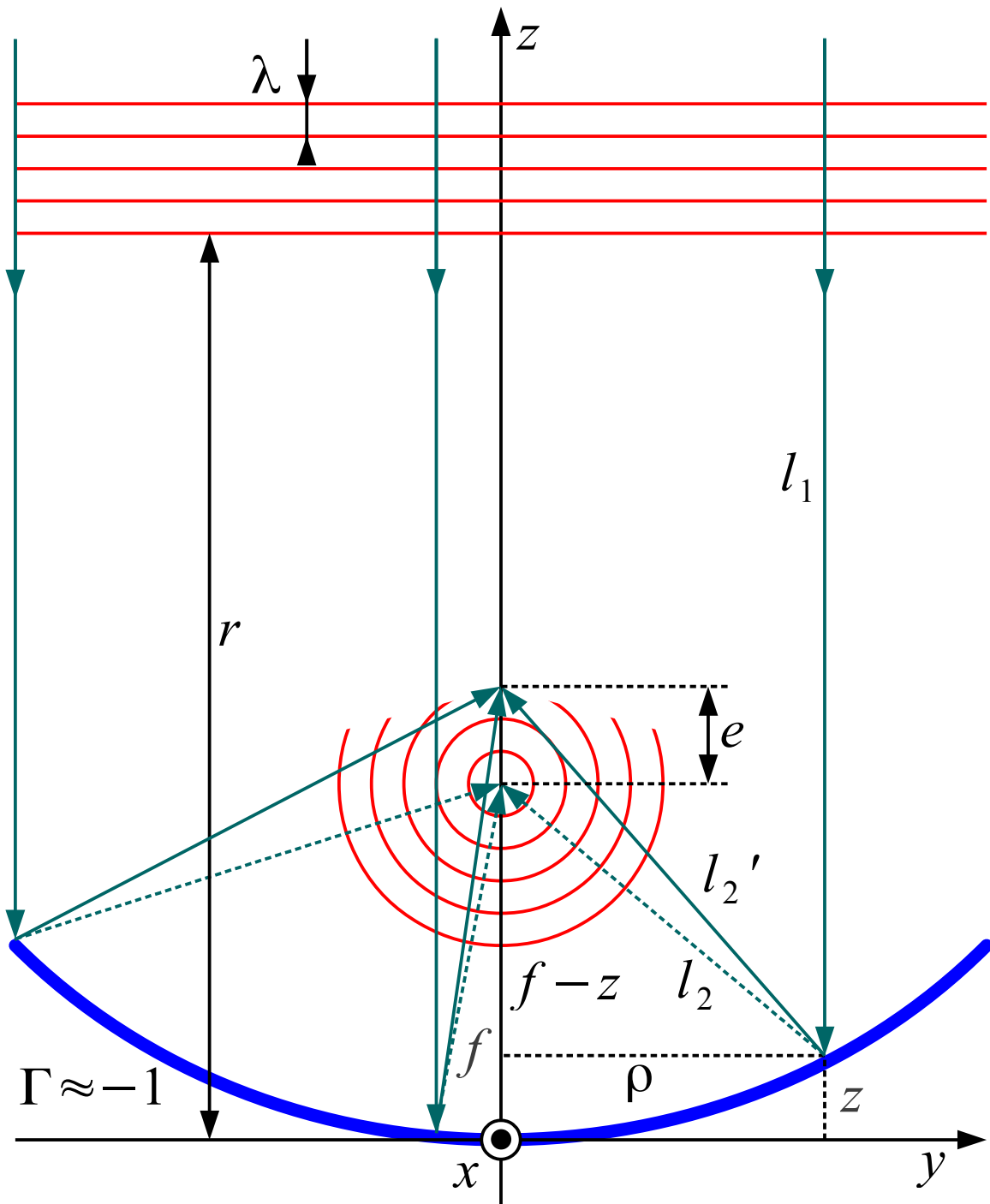
$$F(\Theta = 0) = \frac{8}{d^2} \int_0^{d/2} e^{-j\Delta\phi(2\rho/d)^2} \rho d\rho = \int_0^1 e^{-j\Delta\phi u} du = \frac{e^{-j\Delta\phi} - 1}{-j\Delta\phi} = e^{-j\Delta\phi/2} \frac{\sin(\Delta\phi/2)}{\Delta\phi/2}$$

Kvadratna napaka faze

$$\Delta D_{[\text{dB}]} = 20 \log_{10} |F(\Theta = 0)| = 20 \log_{10} \left| \frac{\sin(\Delta\phi/2)}{\Delta\phi/2} \right|$$

Kvadratna napaka faze odprtine premera 8λ





$$l_2 = \sqrt{(f-z)^2 + \rho^2} \quad \rho = \sqrt{x^2 + y^2}$$

$$l_2' = \sqrt{(e+f-z)^2 + \rho^2} \quad l_1 = r - z$$

$$l_1 + l_2' = r - z + \sqrt{(e+f-z)^2 + \rho^2} = r - z + \sqrt{(f+z)^2 + e^2 + 2ef - 2ez}$$

$$e \ll f$$

$$l_1 + l_2' \approx r + f + \frac{(e^2 + 2ef - 2ez)}{2(f+z)}$$

$$\Delta l \approx e \left[\frac{f-z}{f+z} - 1 \right] = e \frac{-2z}{f+z}$$

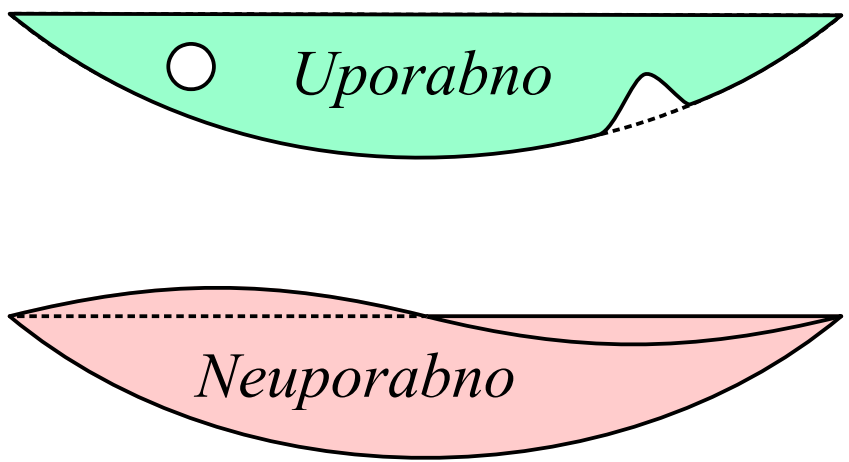
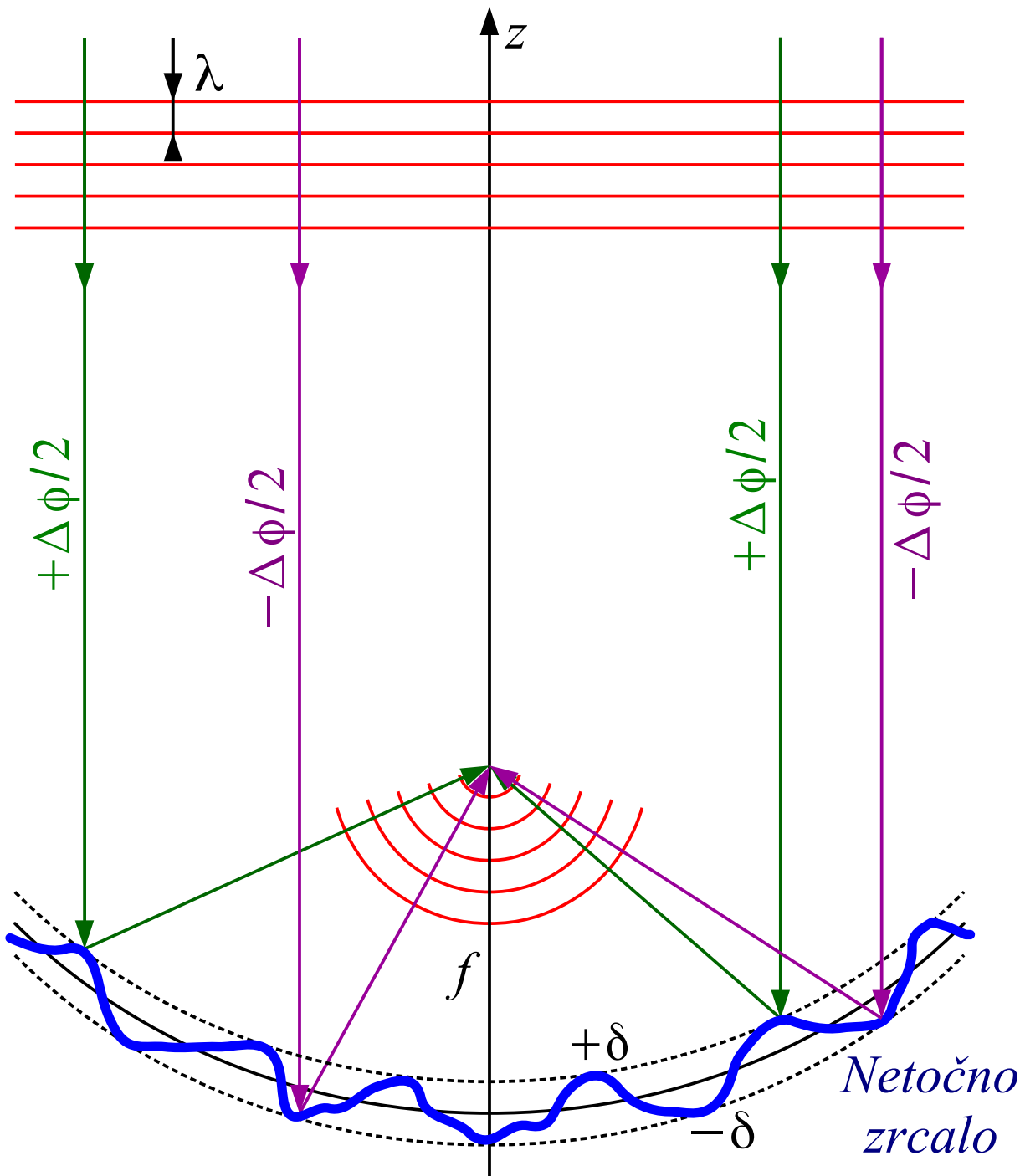
$$\Delta l \approx e \frac{-2\rho^2}{4f^2 + \rho^2}$$

$$z = \frac{\rho^2}{4f}$$

$$\Delta \phi = k \Delta l \approx ke \frac{-2\rho^2}{4f^2 + \rho^2}$$

Ob osi zrcala
 $\rho \ll f \rightarrow \Delta \phi \approx -ke(\rho/f)^2/2$

Osni odmik žarilca



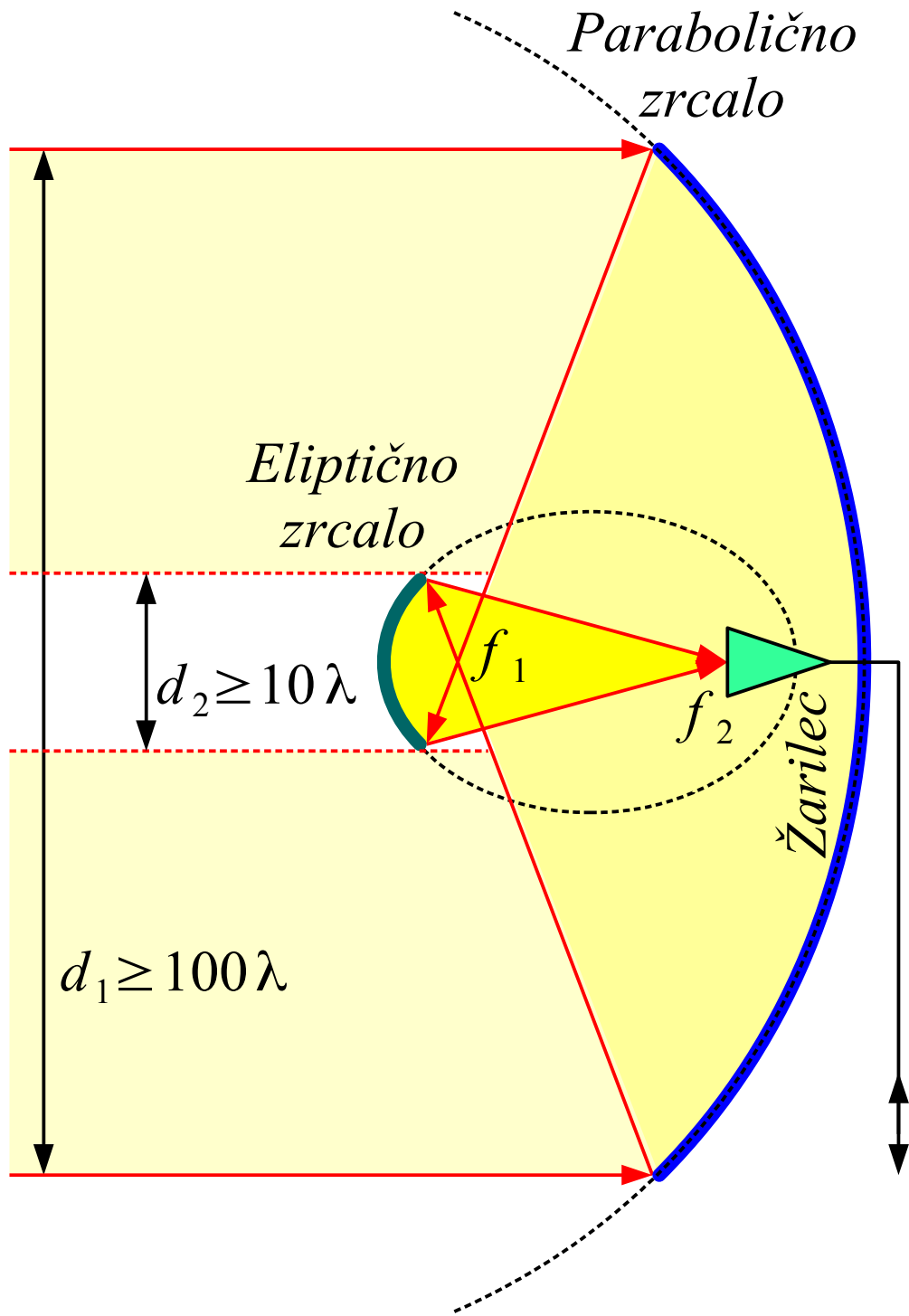
$$\Delta\phi \approx 4k\delta$$

$$\Delta D_{\text{dB}} \approx 20 \log_{10} \left| \frac{\sin(\Delta\phi/2)}{\Delta\phi/2} \right|$$

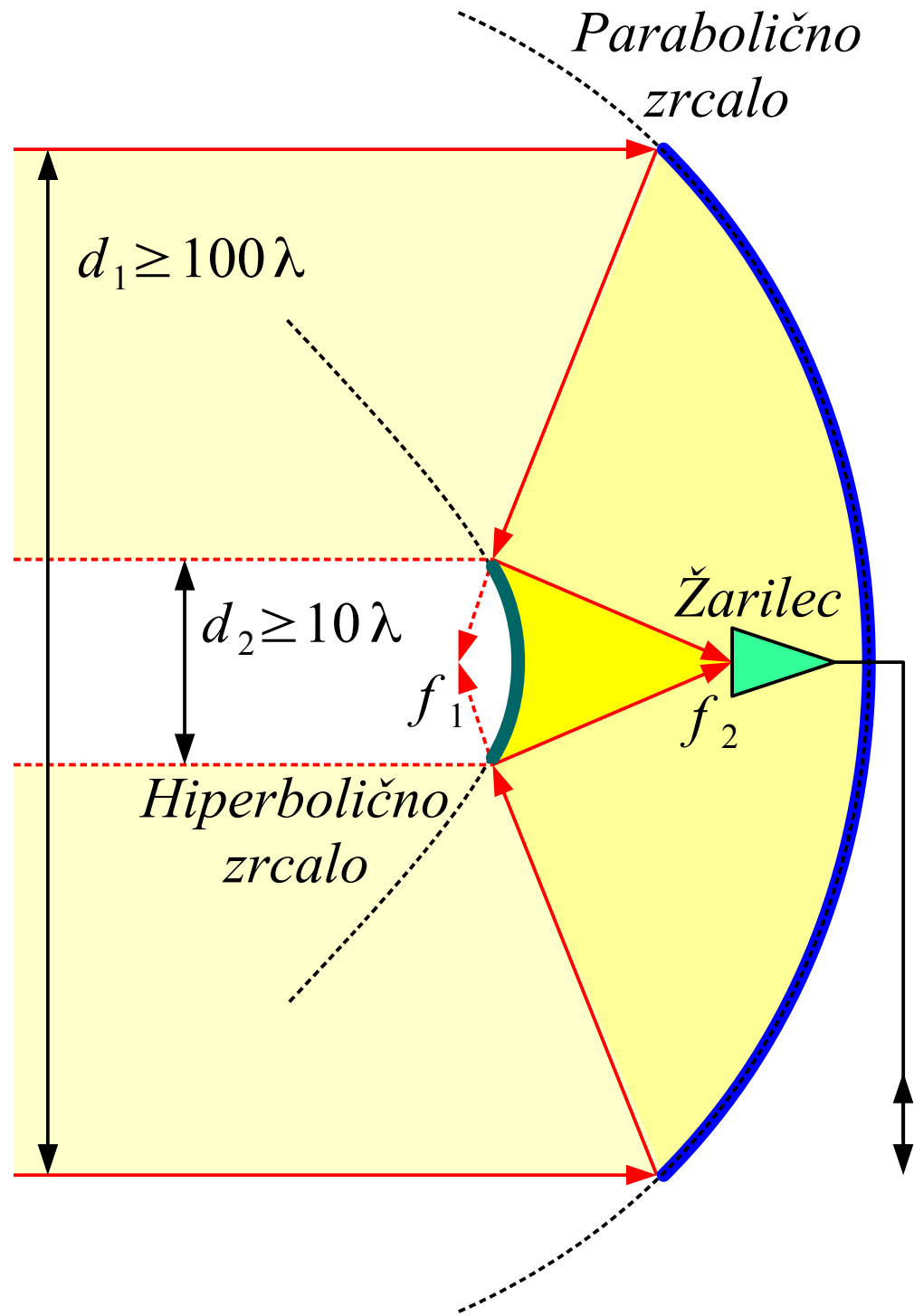
| $\pm\delta$ | $\Delta\phi$ | $\Delta D[\text{dB}]$ |
|-----------------|--------------|-----------------------|
| $\pm\lambda/4$ | 2π | $-\infty$ |
| $\pm\lambda/8$ | π | -3.922 |
| $\pm\lambda/16$ | $\pi/2$ | -0.912 |
| $\pm\lambda/32$ | $\pi/4$ | -0.224 |

Napake oblike zrcala

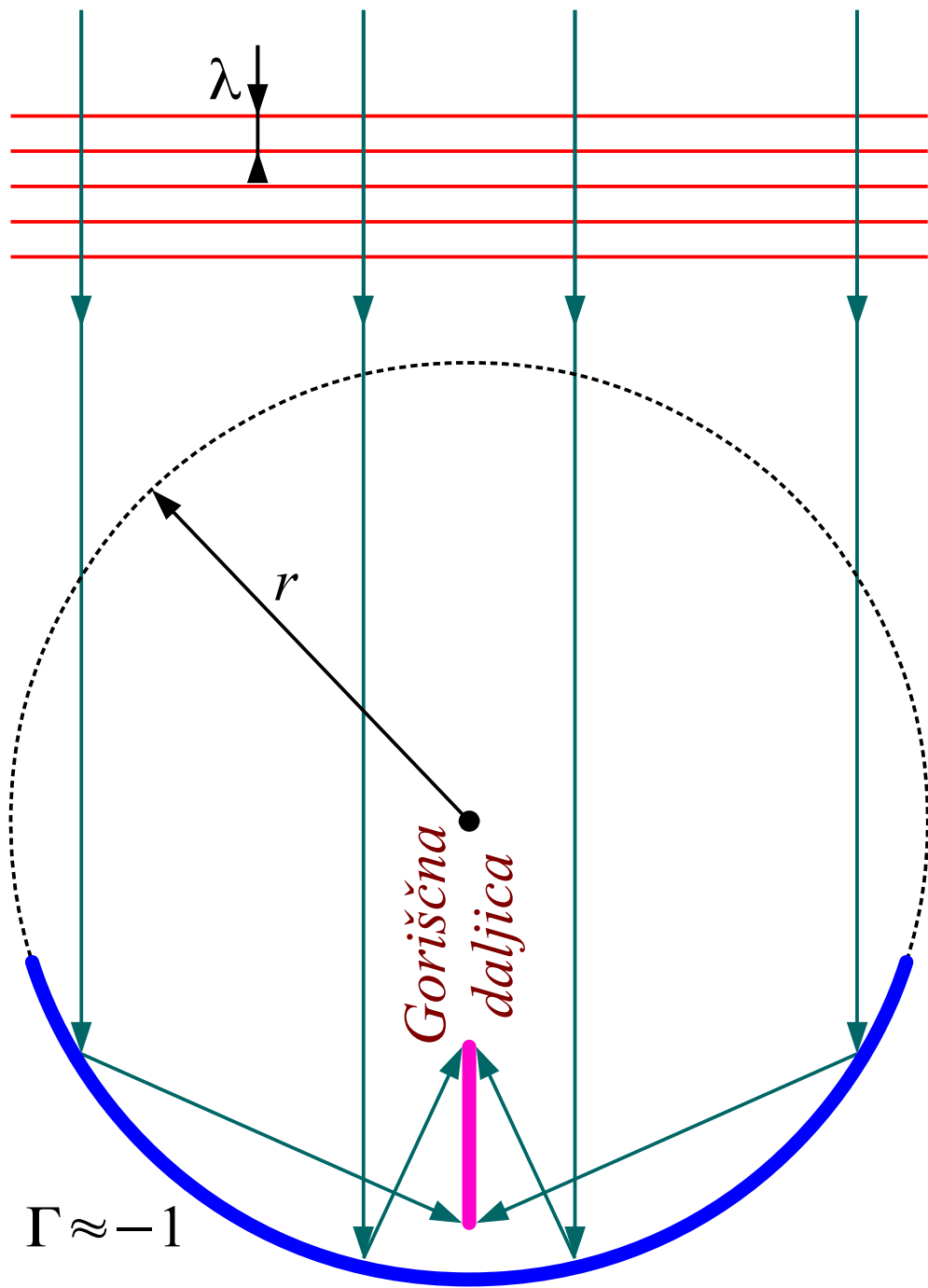
Zgled: $f = 12\text{GHz}$ $\lambda = 25\text{mm}$ $\pm\delta = \pm 0.8\text{mm}$



Gregorijanska antena



Cassegrainova antena



Krogelno zrcalo

