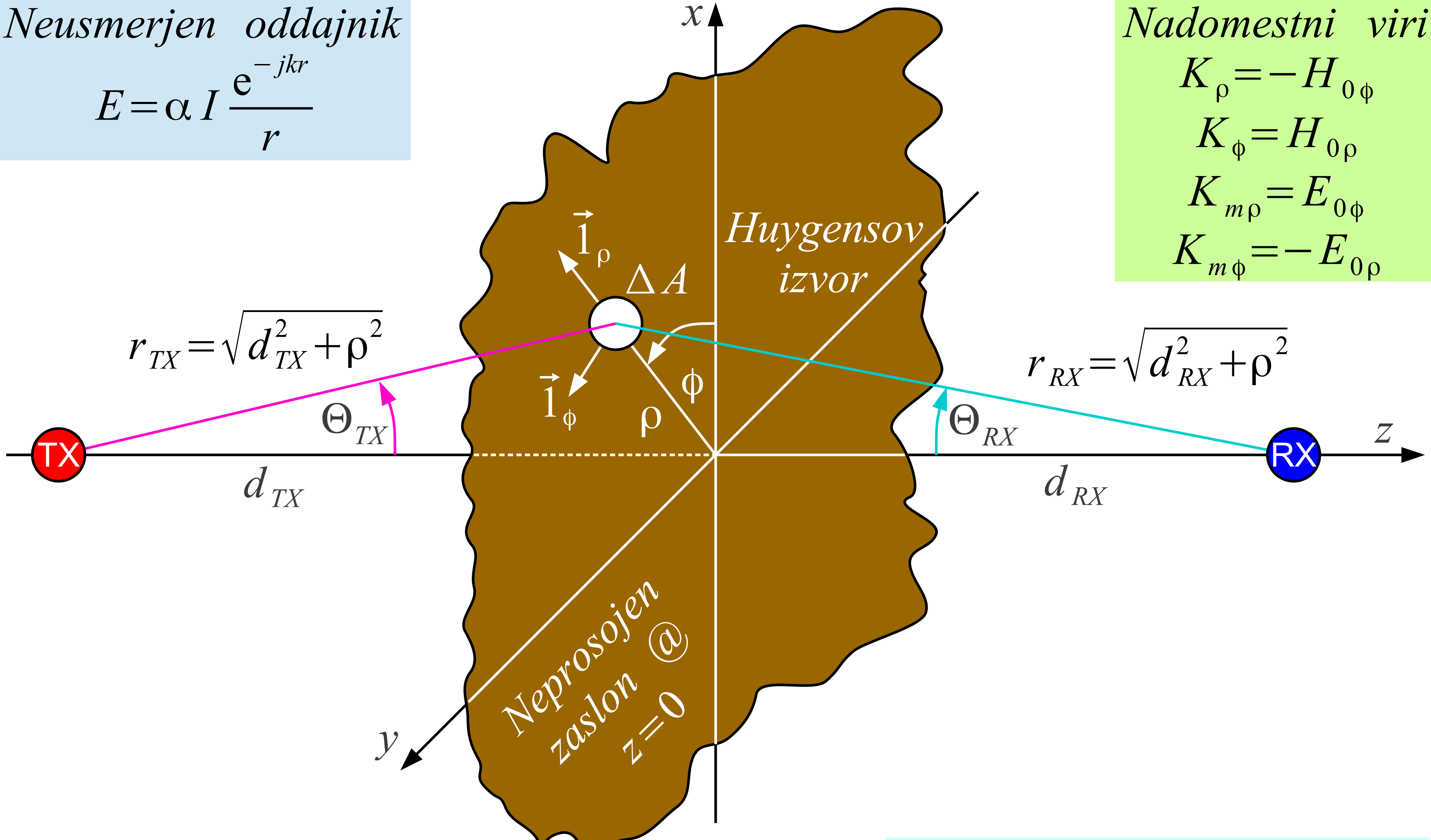
Uklon

Neusmerjen oddajnik

$$E=\alpha I\,\frac{e^{-jkr}}{r}$$

Nadomestni viri

$$K_\rho=-H_{0\phi}$$
$$K_\phi=H_{0\rho}$$
$$K_{m\rho}=E_{0\phi}$$
$$K_{m\phi}=-E_{0\rho}$$



Neovirano polje $r=d_{TX}+d_{RX}$

$$E_\infty=\alpha I\,\frac{e^{-jkr}}{r}=\alpha I\,\frac{e^{-jk(d_{TX}+d_{RX})}}{d_{TX}+d_{RX}}$$

<u>Huygensov izvor</u>

Neusmerjen oddajnik

$$E=\alpha I \frac{e^{-jkr}}{r}$$

Odprtina

$$E_{0\rho}=\alpha I_{\rho} \frac{e^{-jkr_{TX}}}{r_{TX}} \cos\Theta_{TX}$$

$$E_{0\phi}=\alpha I_{\phi} \frac{e^{-jkr_{TX}}}{r_{TX}}$$

$$H_{0\rho}=-\frac{\alpha}{Z_0} I_{\phi} \frac{e^{-jkr_{TX}}}{r_{TX}} \cos\Theta_{TX}$$

$$H_{0\phi}=\frac{\alpha}{Z_0} I_{\rho} \frac{e^{-jkr_{TX}}}{r_{TX}}$$

Nadomestni viri

$$K_{\rho}=-H_{0\phi}$$

$$K_{\phi}=H_{0\rho}$$

$$K_{m\rho}=E_{0\phi}$$

$$K_{m\phi}=-E_{0\rho}$$

Enakovreden zapis

$$\frac{jk}{4\pi}=\frac{j}{2\lambda}$$

Neusmerjen sprejemnik

$$E_{\rho}=\frac{jk}{4\pi}\left(-K_{\rho} Z_0 \cos\Theta_{RX}-K_{m\phi}\right)\Delta A \frac{e^{-jkr_{RX}}}{r_{RX}}$$

$$E_{\phi}=\frac{jk}{4\pi}\left(-K_{\phi} Z_0+K_{m\rho} \cos\Theta_{RX}\right)\Delta A \frac{e^{-jkr_{RX}}}{r_{RX}}$$

Rezultat je neodvisen od polarizacije:

$$E=\frac{jk}{4\pi}\alpha I \Delta A \frac{e^{-jkr_{TX}}}{r_{TX}} \frac{e^{-jkr_{RX}}}{r_{RX}}\left(\cos\Theta_{TX}+\cos\Theta_{RX}\right)$$

Uklon valovanja na Huygensovem izvoru

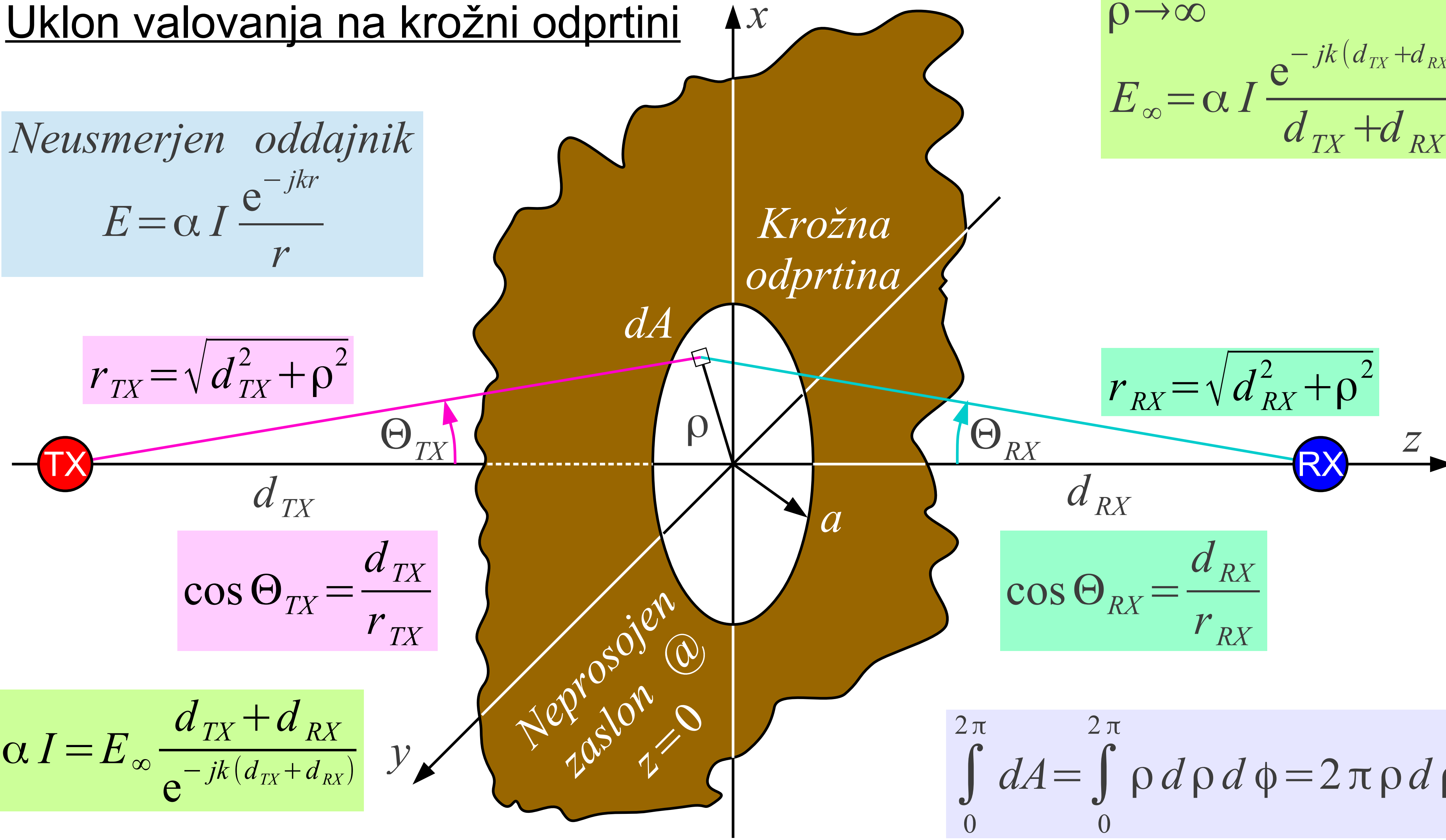
Uklon valovanja na krožni odprtini

Neusmerjen oddajnik

$$E = \alpha I \frac{e^{-jkr}}{r}$$

$$\rho \to \infty$$

$$E_\infty = \alpha I \frac{e^{-jk(d_{TX}+d_{RX})}}{d_{TX}+d_{RX}}$$



$$r_{TX} = \sqrt{d_{TX}^2 + \rho^2}$$

$$r_{RX} = \sqrt{d_{RX}^2 + \rho^2}$$

Θ_{TX} $\quad d_{TX}$ $\qquad \Theta_{RX}$ $\quad d_{RX}$

$$\cos\Theta_{TX} = \frac{d_{TX}}{r_{TX}}$$

$$\cos\Theta_{RX} = \frac{d_{RX}}{r_{RX}}$$

$$\alpha I = E_\infty \frac{d_{TX}+d_{RX}}{e^{-jk(d_{TX}+d_{RX})}}$$

$$\int_0^{2\pi} dA = \int_0^{2\pi} \rho \, d\rho \, d\phi = 2\pi\rho \, d\rho$$

$$E = E_\infty \frac{jk}{4\pi} \frac{d_{TX}+d_{RX}}{e^{-jk(d_{TX}+d_{RX})}} \iint \frac{e^{-jkr_{TX}}}{r_{TX}} \frac{e^{-jkr_{RX}}}{r_{RX}} (\cos\Theta_{TX} + \cos\Theta_{RX}) \, dA$$

$$E = E_\infty jk \frac{d_{TX}+d_{RX}}{e^{-jk(d_{TX}+d_{RX})}} \int_0^a \frac{e^{-jk(r_{TX}+r_{RX})}}{r_{TX} r_{RX}} \frac{\cos\Theta_{TX} + \cos\Theta_{RX}}{2} \rho \, d\rho$$

Približek uklona na krožni odprtini

$$a \ll d_{TX}, d_{RX} \;\rightarrow\; E \approx E_\infty jk \frac{d_{TX}+d_{RX}}{2 d_{TX} d_{RX}} \int_0^{a^2} \mathrm{e}^{-jk\frac{d_{TX}+d_{RX}}{2 d_{RX} d_{TX}}\rho^2} d\rho^2$$

$$\cos\Theta_{TX} \approx 1 \approx \cos\Theta_{RX}$$

$$\frac{1}{r_{TX} r_{RX}} \approx \frac{1}{d_{RX} d_{TX}}$$

$$\mathrm{e}^{-jkr_{TX}} \approx \mathrm{e}^{-jkd_{TX}} \mathrm{e}^{\frac{-jk\rho^2}{2 d_{TX}}}$$

$$\mathrm{e}^{-jkr_{RX}} \approx \mathrm{e}^{-jkd_{RX}} \mathrm{e}^{\frac{-jk\rho^2}{2 d_{RX}}}$$

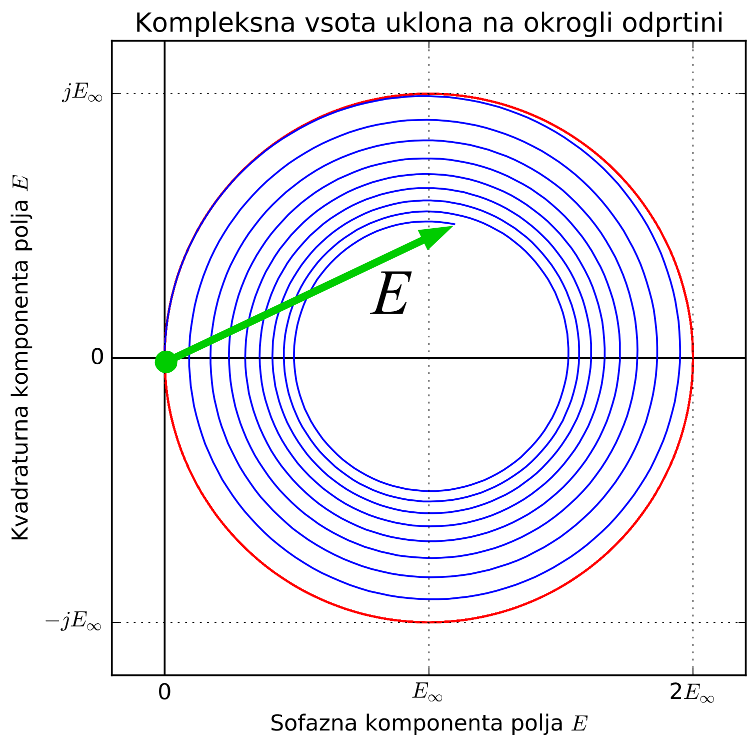
Neposredni žarek — *Uklon na robu odprtine*

$$E \approx E_\infty \left[1 - \mathrm{e}^{-jk\frac{d_{TX}+d_{RX}}{2 d_{RX} d_{TX}} a^2} \right]$$

Zgled $\lambda = 10\mathrm{cm}$

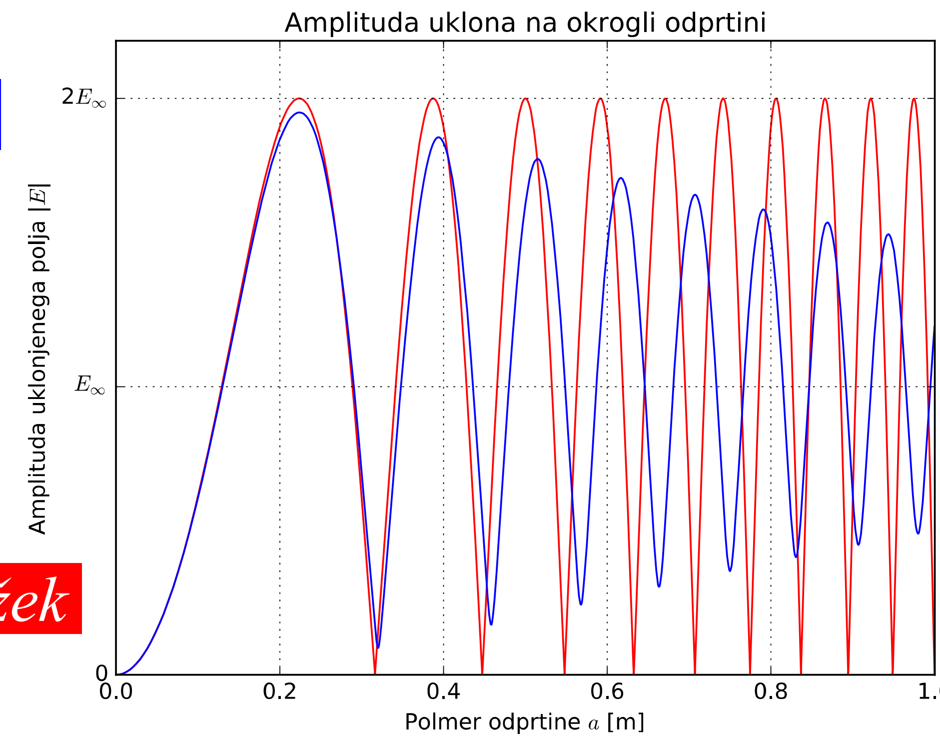
$d_{TX} = 1\mathrm{m}$ $d_{RX} = 1\mathrm{m}$

$$|E| \approx 2 \left| E_\infty \sin\left(k \frac{d_{TX}+d_{RX}}{4 d_{TX} d_{RX}} a^2 \right) \right|$$

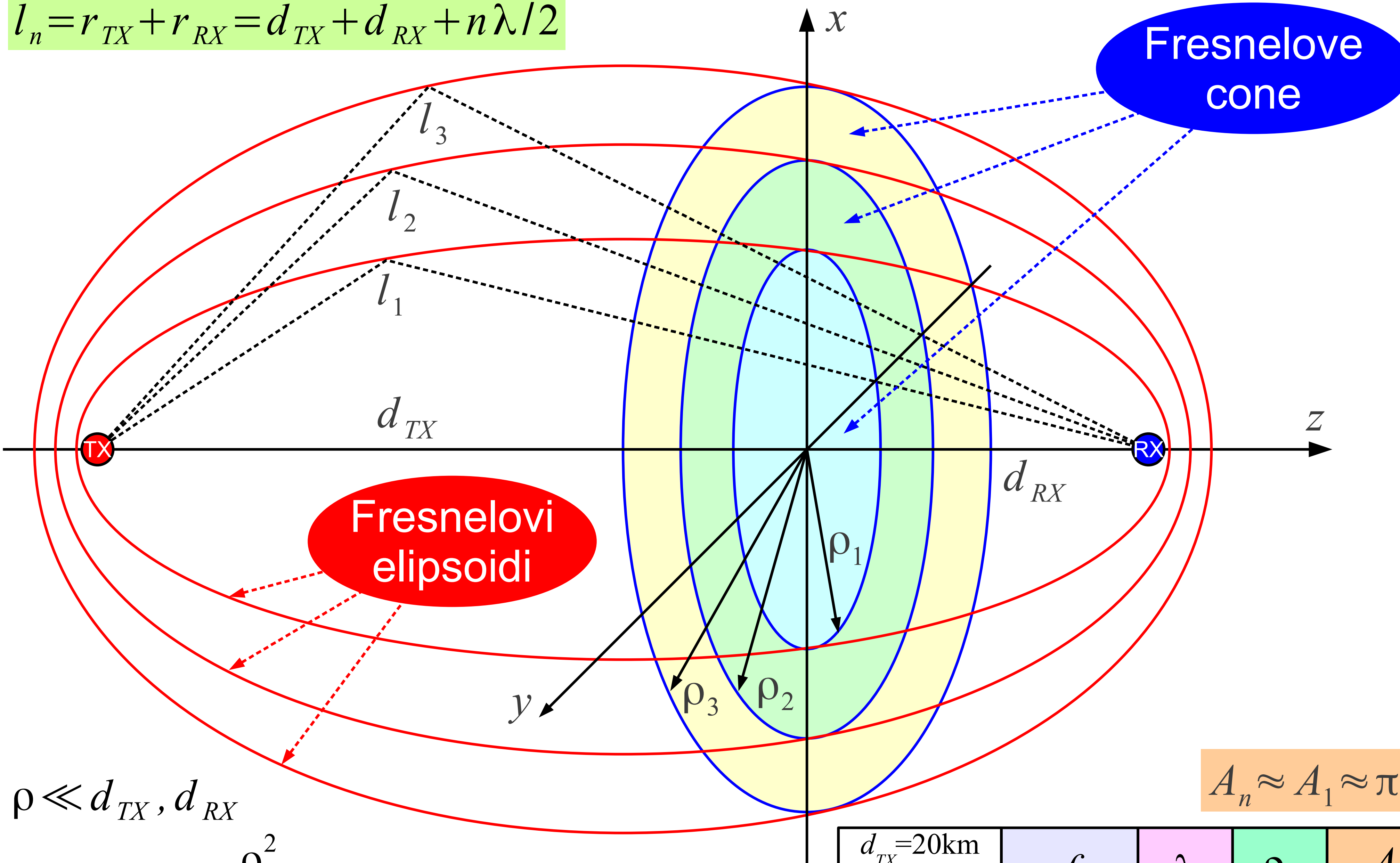


Točno

Približek



$$l_n = r_{TX} + r_{RX} = d_{TX} + d_{RX} + n\lambda/2$$



$$A_n \approx A_1 \approx \pi \rho_1^2$$

$$\rho \ll d_{TX}, d_{RX}$$

$$r_{TX} \approx d_{TX} + \frac{\rho^2}{2d_{TX}}$$

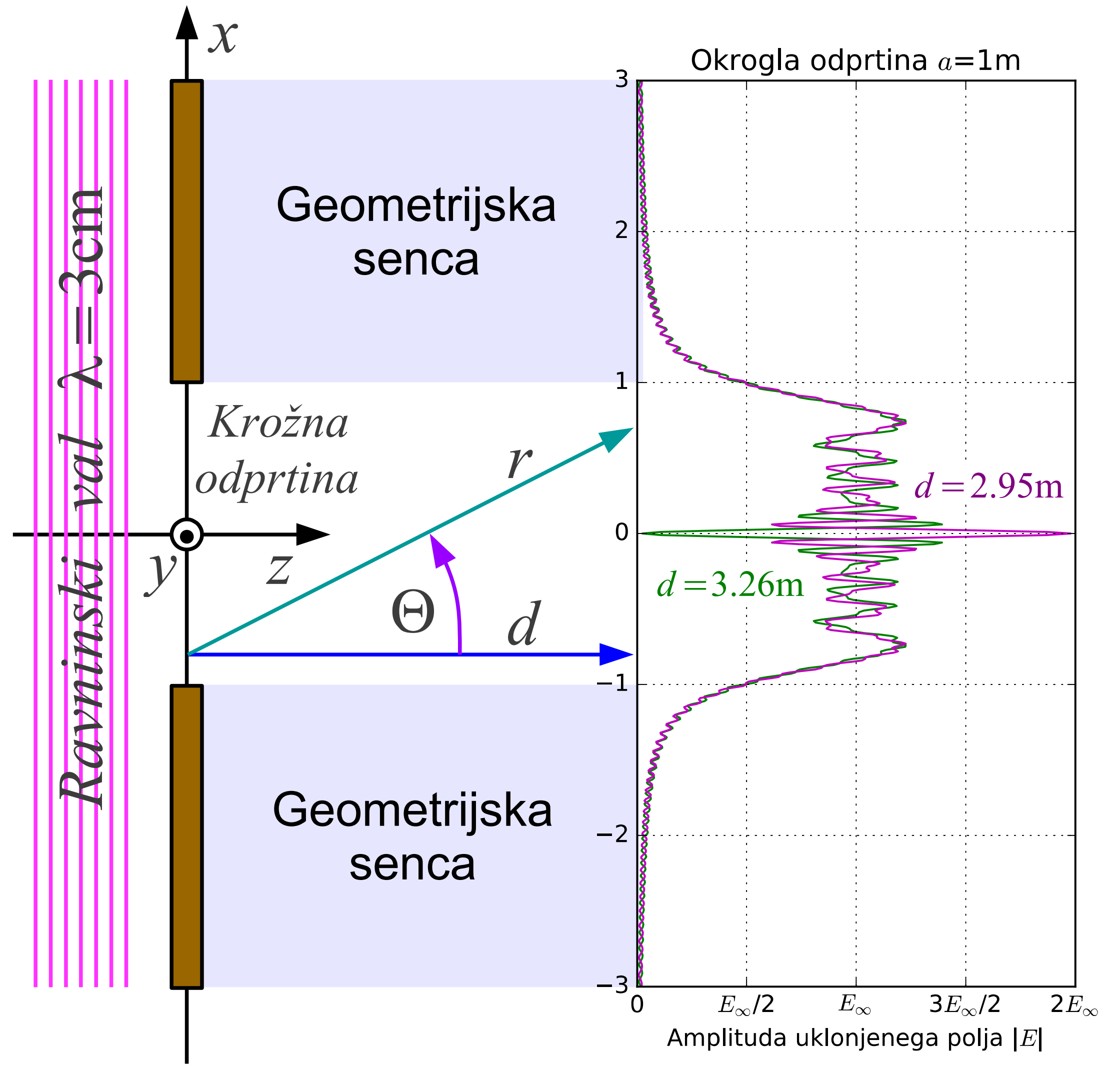
$$r_{RX} \approx d_{RX} + \frac{\rho^2}{2d_{RX}}$$

$$\rho_n \approx \sqrt{n\lambda \frac{d_{TX} d_{RX}}{d_{TX} + d_{RX}}}$$

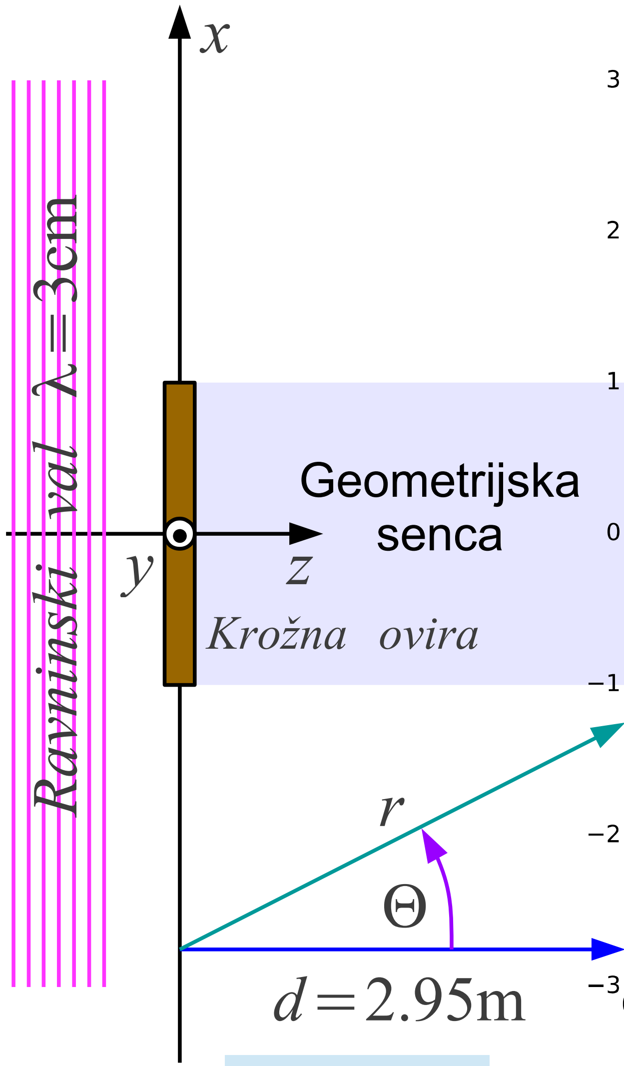
d_{TX}=20km d_{RX}=10km	f	λ	ρ_1	A_1
Radio	100MHz	3m	141m	62831m^2
Mikrovalovi	10GHz	3cm	14.1m	628m^2
Svetloba	600THz	0.5µm	5.8cm	0.0105m^2

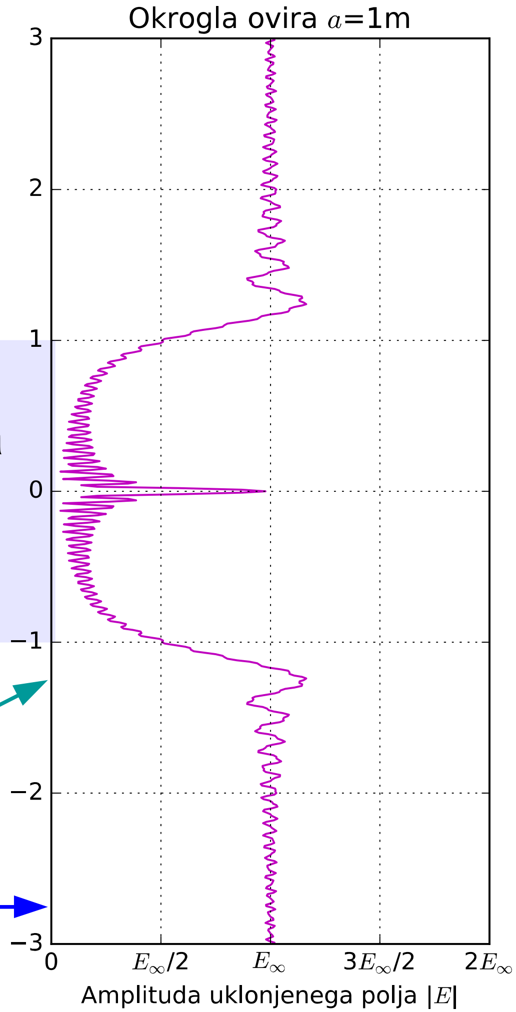
$$r=\sqrt{(\rho\cos\phi-x)^2+(\rho\sin\phi)^2+d^2}$$

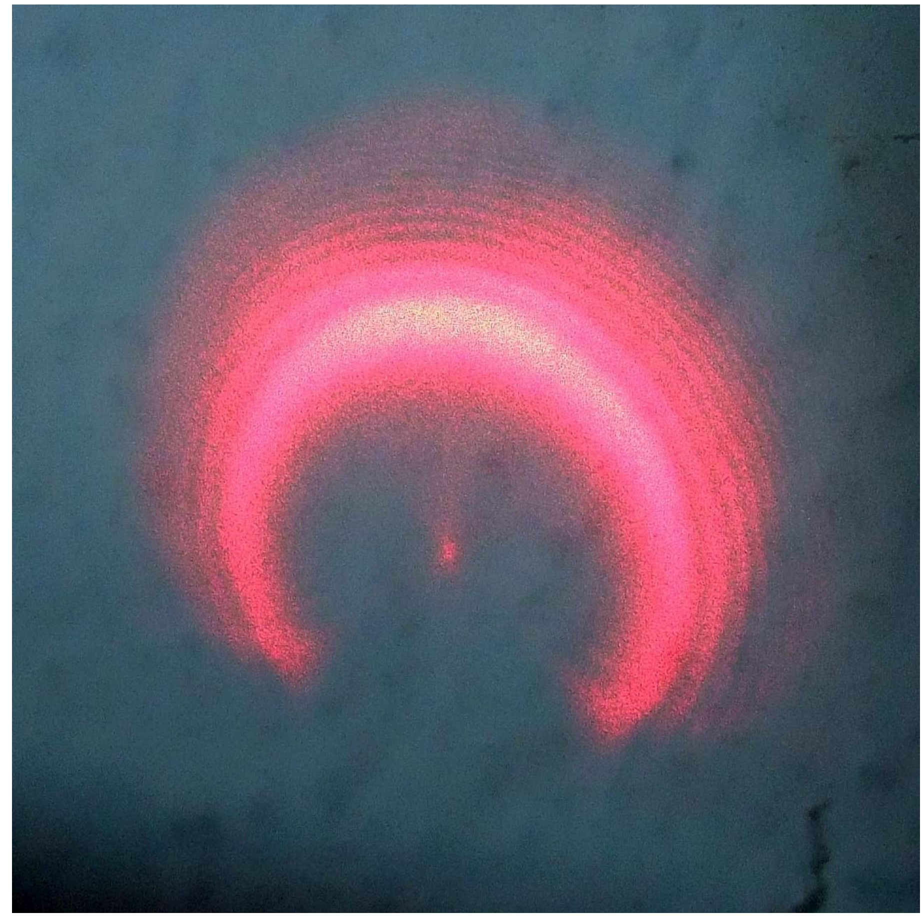
$$E_{odprtina}=E_{\infty}\frac{jk\,e^{jkd}}{4\pi}\int_0^a\int_0^{2\pi}\frac{e^{-jkr}}{r}\left(1+\frac{d}{r}\right)\rho\,d\rho\,d\phi$$



Aragova pika za krožno odprtino







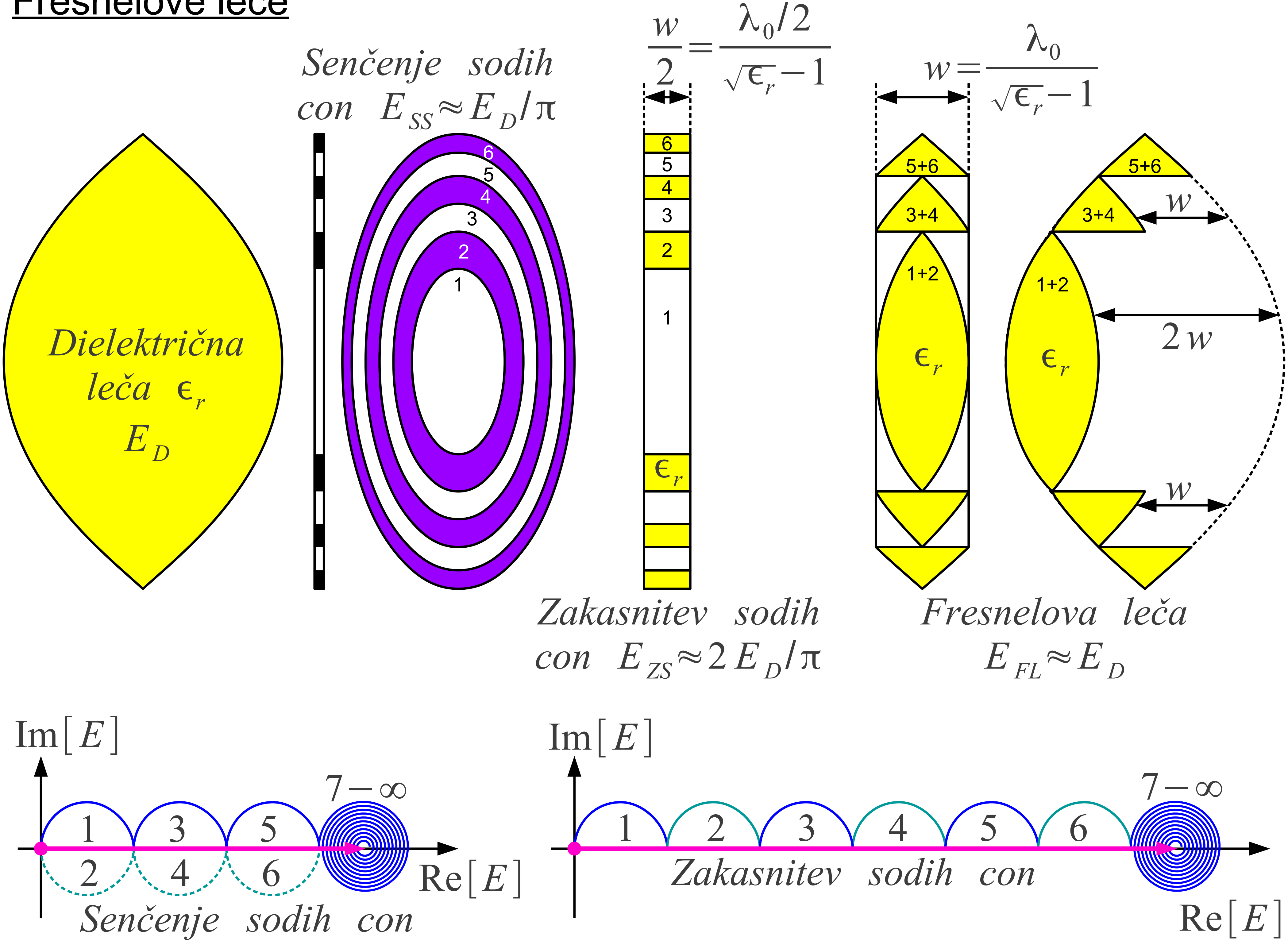
$$\cos\Theta = \frac{d}{r}$$

$$E_{ovira} = E_{\infty} - E_{odprtina}$$

$$E_{ovira} = E_{\infty}\frac{jk\,e^{jkd}}{4\pi}\int_{a}^{\infty}\int_{0}^{2\pi}\frac{e^{-jkr}}{r}\left(1+\frac{d}{r}\right)\rho\,d\rho\,d\phi$$

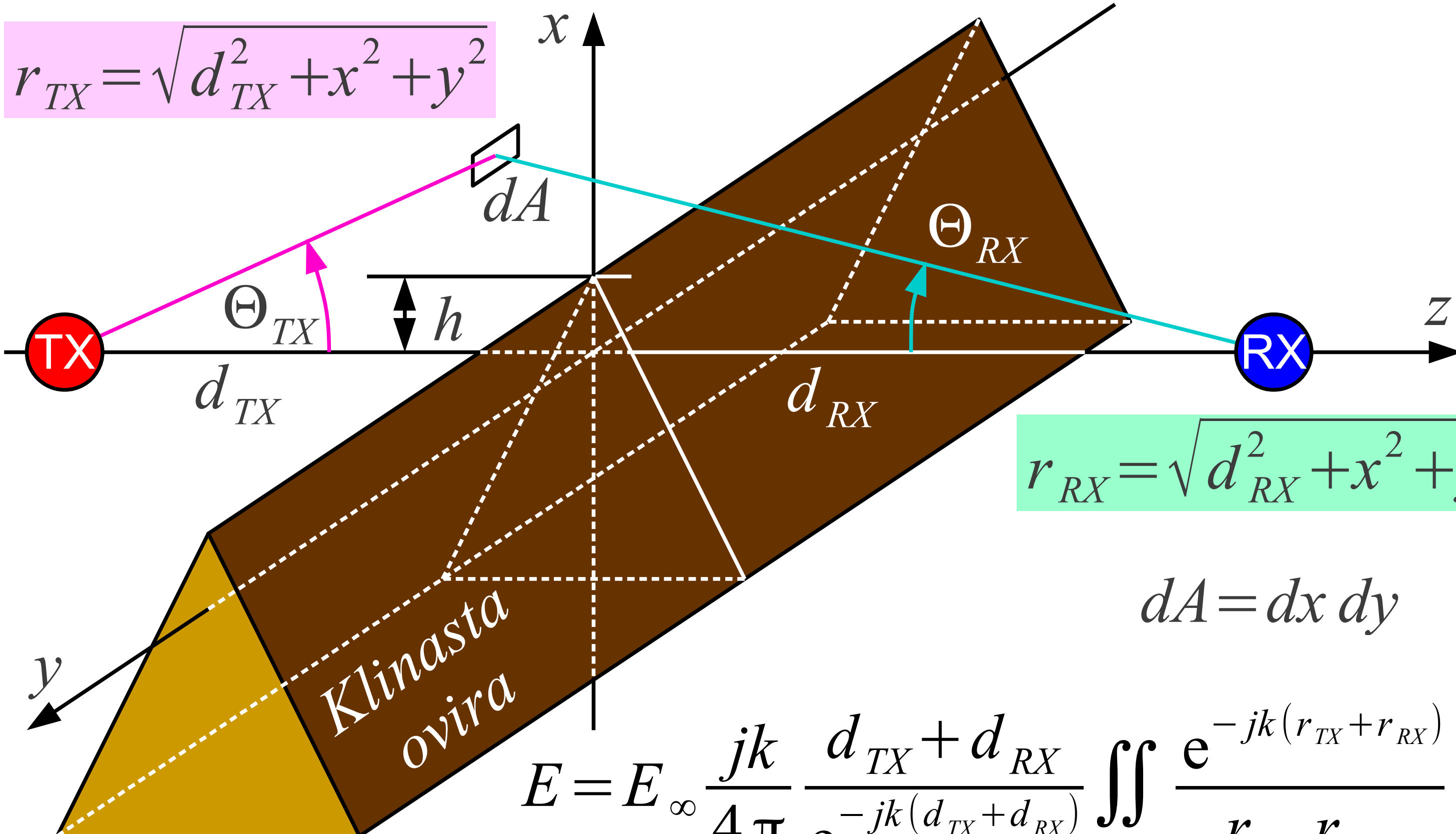
Aragova pika za krožno oviro

Fresnelove leče



Prečna klinasta ovira

$$r_{TX}=\sqrt{d_{TX}^2+x^2+y^2}$$



$$r_{RX}=\sqrt{d_{RX}^2+x^2+y^2}$$

$$dA=dx\,dy$$

$$x, y \ll d_{TX}, d_{RX}$$

$$\cos\Theta_{TX}\approx 1\approx\cos\Theta_{RX}$$

$$\frac{1}{r_{TX}r_{RX}}\approx\frac{1}{d_{RX}d_{TX}}$$

$$r_i\approx d_i+\frac{x^2+y^2}{2d_i}$$

$$E=E_\infty\frac{jk}{4\pi}\frac{d_{TX}+d_{RX}}{e^{-jk(d_{TX}+d_{RX})}}\iint\frac{e^{-jk(r_{TX}+r_{RX})}}{r_{TX}r_{RX}}(\cos\Theta_{TX}+\cos\Theta_{RX})\,dx\,dy$$

$$e^{-jk(r_{TX}+r_{RX})}\approx e^{-jk(d_{TX}+d_{RX})}e^{-jk\frac{d_{TX}+d_{RX}}{2d_{TX}d_{RX}}(x^2+y^2)}\approx e^{-jk(d_{TX}+d_{RX})}e^{-j\pi\frac{x^2+y^2}{\rho_1^2}}$$

$$\frac{2\pi}{k}\frac{d_{TX}d_{RX}}{d_{TX}+d_{RX}}\approx\rho_1^2$$

$$E=E_\infty\frac{j}{\rho_1^2}\int_h^\infty e^{-j\pi\frac{x^2}{\rho_1^2}}dx\int_{-\infty}^\infty e^{-j\pi\frac{y^2}{\rho_1^2}}dy$$

$$u=\frac{\sqrt{\pi}}{\rho_1}x$$

$$v=\frac{\sqrt{\pi}}{\rho_1}y$$

$$E=E_\infty\frac{j}{\pi}\int_{\frac{\sqrt{\pi}}{\rho_1}h}^\infty e^{-ju^2}du\int_{-\infty}^\infty e^{-jv^2}dv$$

$$\left[\int_{-\infty}^\infty e^{-jv^2}dv\right]^2=-j\pi\ \rightarrow\ \int_{-\infty}^\infty e^{-jv^2}dv=(1-j)\sqrt{\frac{\pi}{2}}$$

$$E=E_\infty\frac{1+j}{\sqrt{2\pi}}\int_{\frac{\sqrt{\pi}}{\rho_1}h}^\infty e^{-ju^2}du$$

Eulerjeva
ali
Cornujeva
spirala

$$\int_{-\infty}^{\infty} e^{-ju^2}\,du =$$

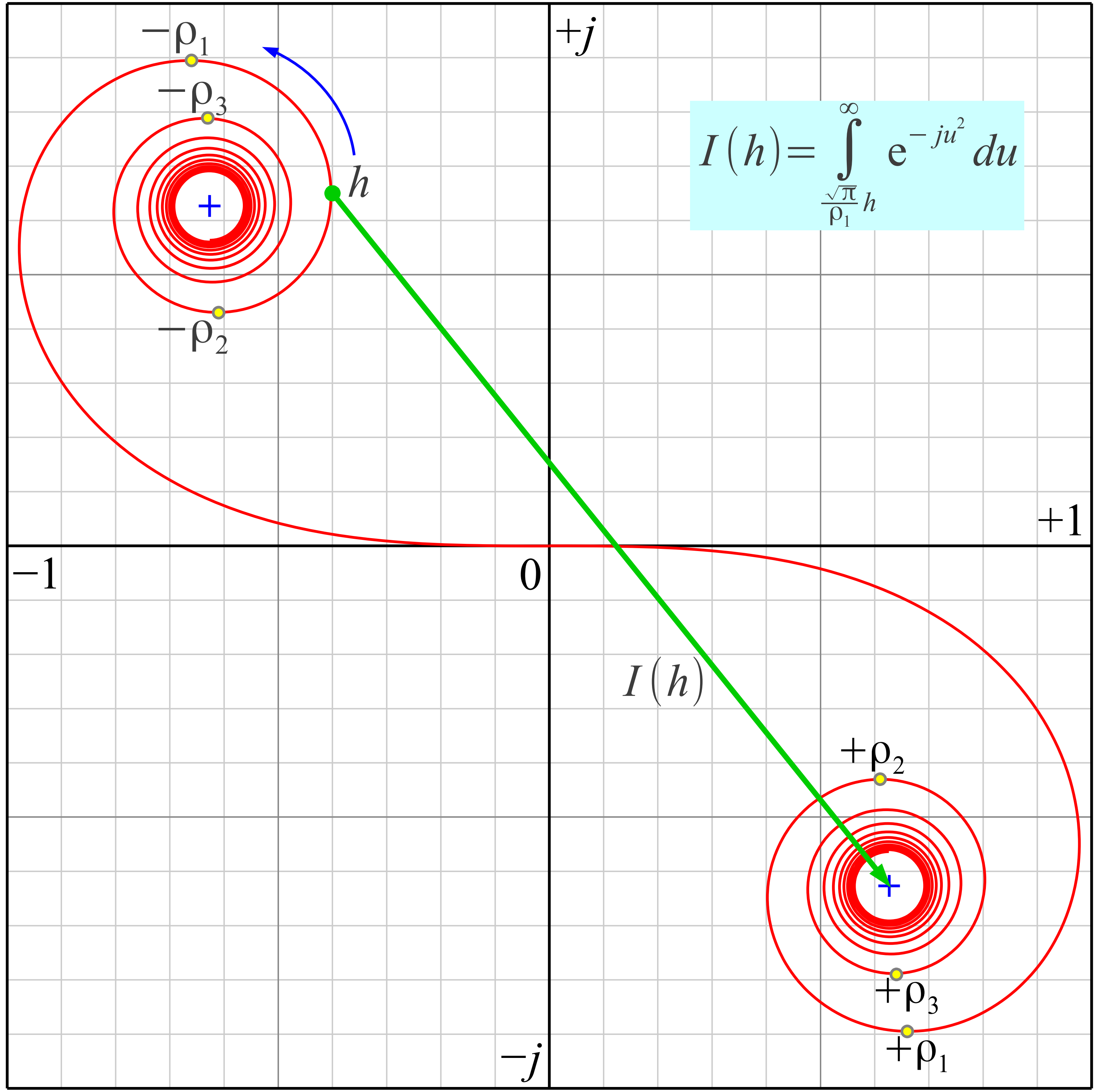
$$= (1-j)\sqrt{\frac{\pi}{2}}$$

Fresnelova integrala

$$\int_{0}^{x} e^{-jt^2}\,dt =$$

$$= \int_{0}^{x} \cos(t^2)\,dt -$$

$$- j\int_{0}^{x} \sin(t^2)\,dt$$



<u>Klotoida</u>

$$E = E_\infty \frac{1+j}{\sqrt{2\pi}} \int_{\frac{\sqrt{\pi}}{\rho_1}h}^{\infty} \mathrm{e}^{-j u^2} du$$

$$\left|\frac{E}{E_\infty}\right| = \frac{1}{\sqrt{\pi}} \left| \int_{\frac{\sqrt{\pi}}{\rho_1}h}^{\infty} \mathrm{e}^{-j u^2} du \right|$$

$$\left|\frac{E}{E_\infty}\right|_{MAX} = 1.17 \quad @ \quad h = -0.866\rho_1$$

$$a_{\mathrm{dB}} = 20\log_{10}\left(\frac{1}{\sqrt{\pi}} \left| \int_{\frac{\sqrt{\pi}}{\rho_1}h}^{\infty} \mathrm{e}^{-j u^2} du \right| \right)$$

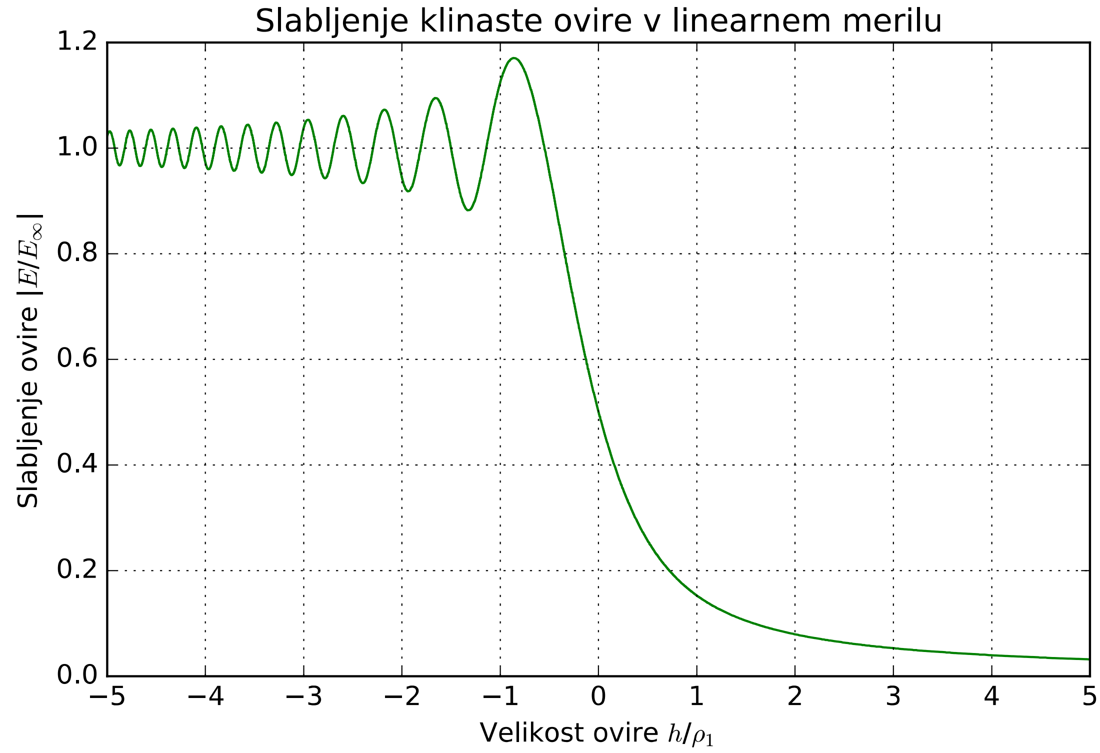
$$h \le -\rho_1 \;\rightarrow\; a_{\mathrm{dB}} \approx 0\mathrm{dB}$$

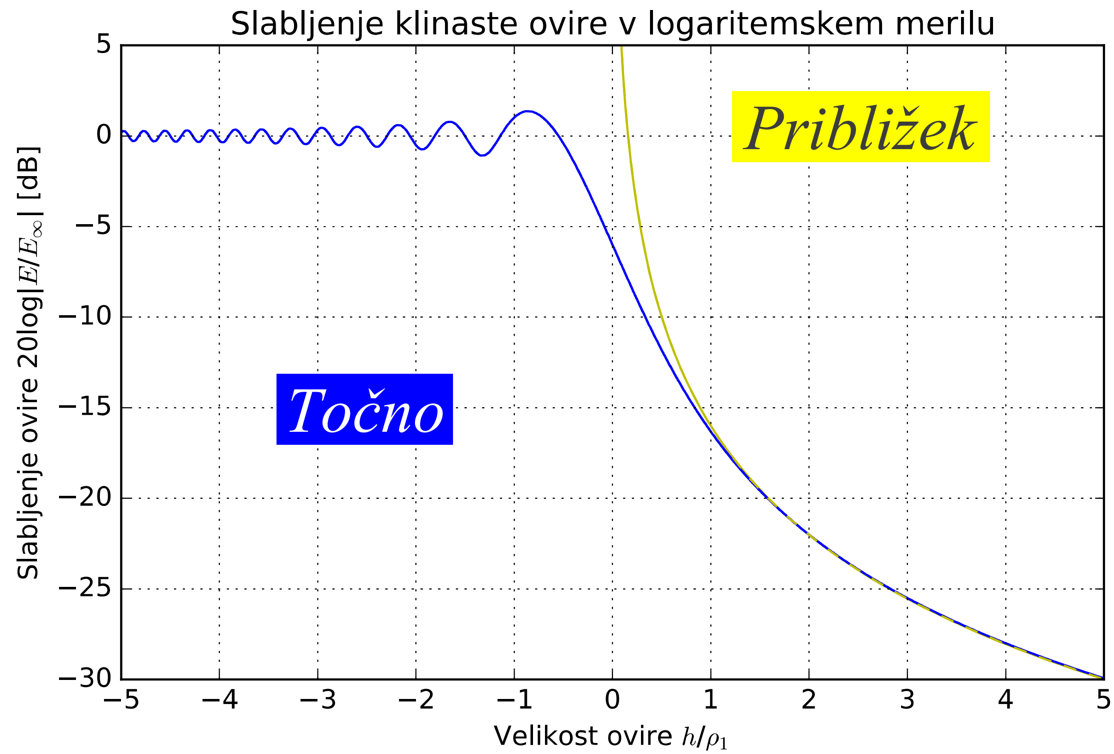
$$a_{MAX} = 1.37\mathrm{dB} \quad @ \quad h = -0.866\rho_1$$

$$h = 0 \;\rightarrow\; a_{\mathrm{dB}} = -6\mathrm{dB}$$

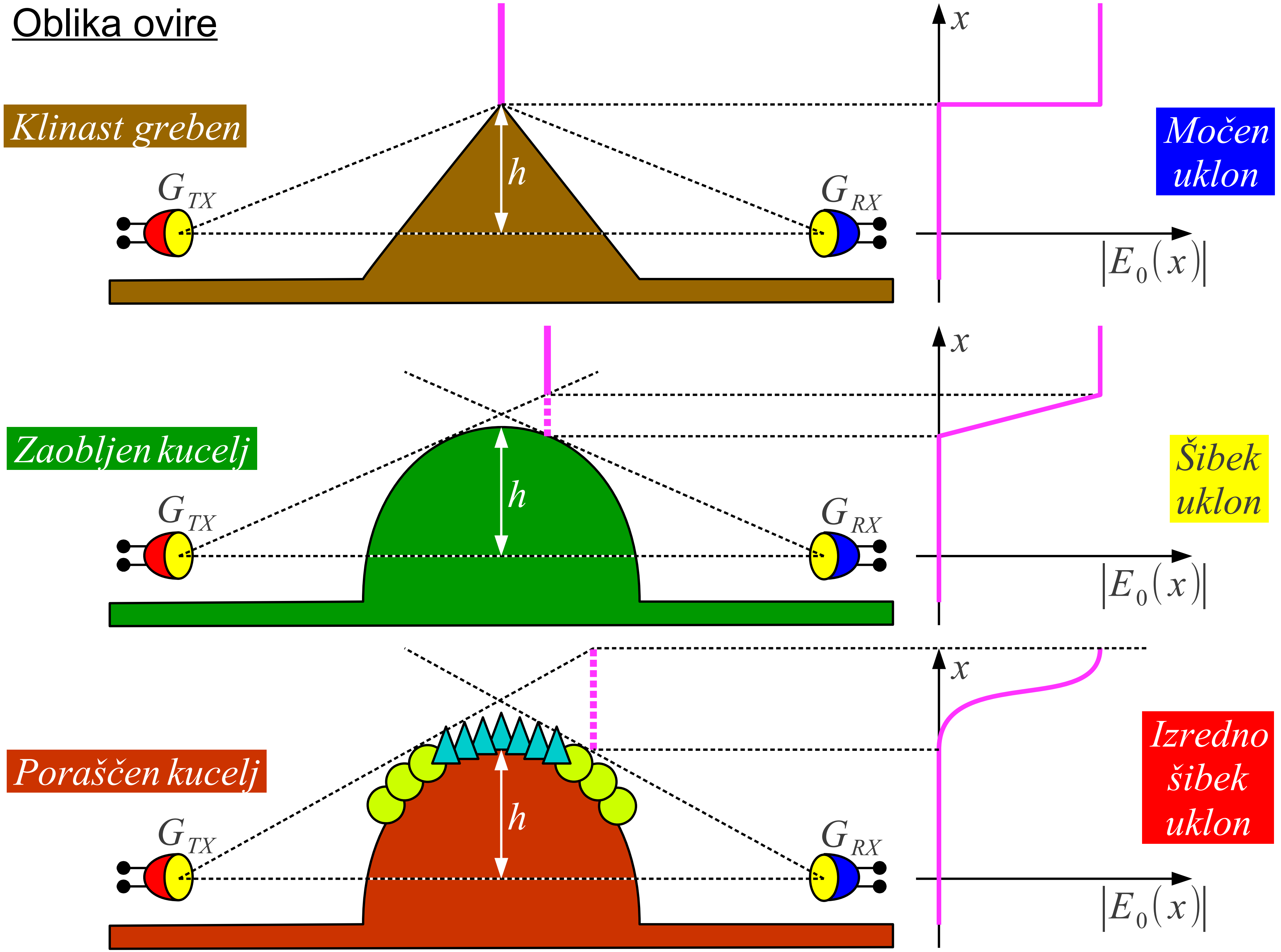
$$\textit{Približek} \quad h \ge \rho_1 \;\rightarrow$$

$$a_{\mathrm{dB}} \approx -16\,\mathrm{dB} - 20\,\mathrm{dB}\log_{10}\frac{h}{\rho_1}$$

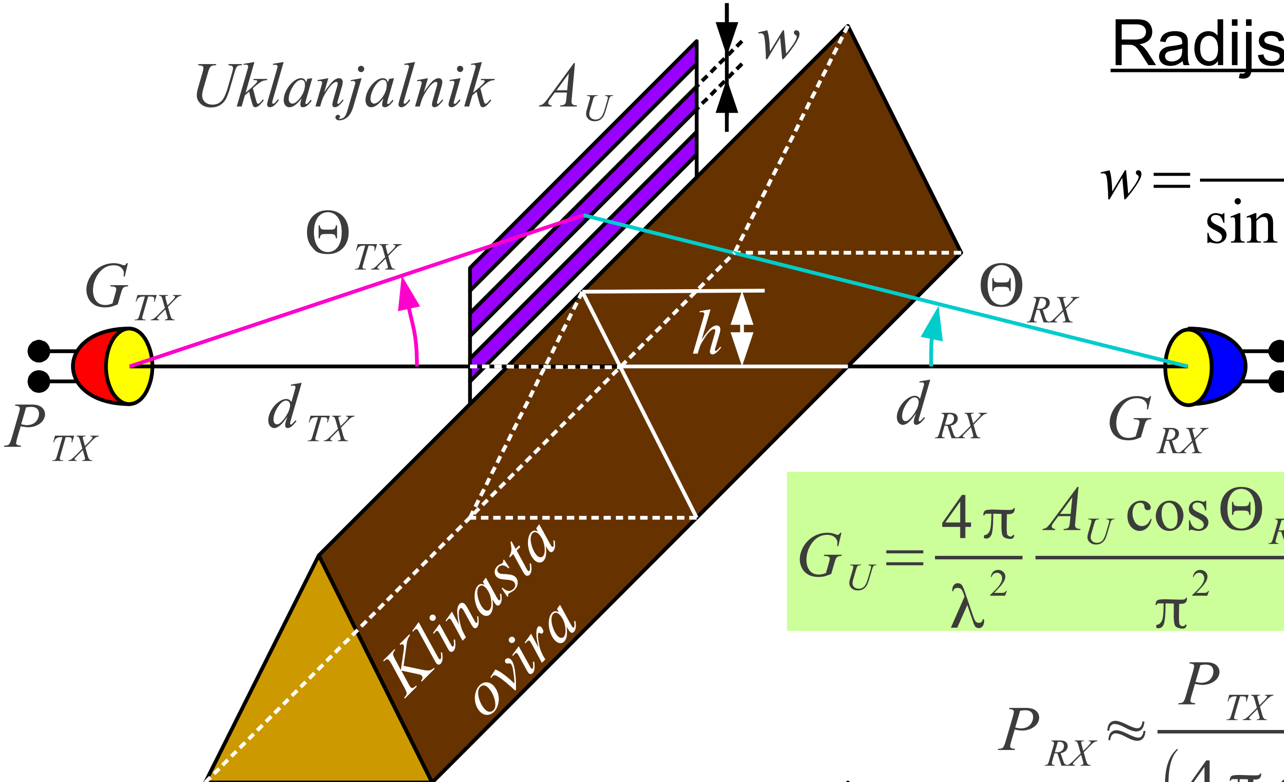




Slabljenje klinaste ovire


Oblika ovire
Klinast greben
Močen uklon
Zaobljen kucelj
Šibek uklon
Poraščen kucelj
Izredno šibek uklon
h
G_{TX}
G_{RX}
x
$|E_0(x)|$

Radijska zveza preko uklanjalnika



$$w=\frac{\lambda/2}{\sin\Theta_{TX}+\sin\Theta_{RX}}\approx\frac{\rho_1^2}{2h}$$

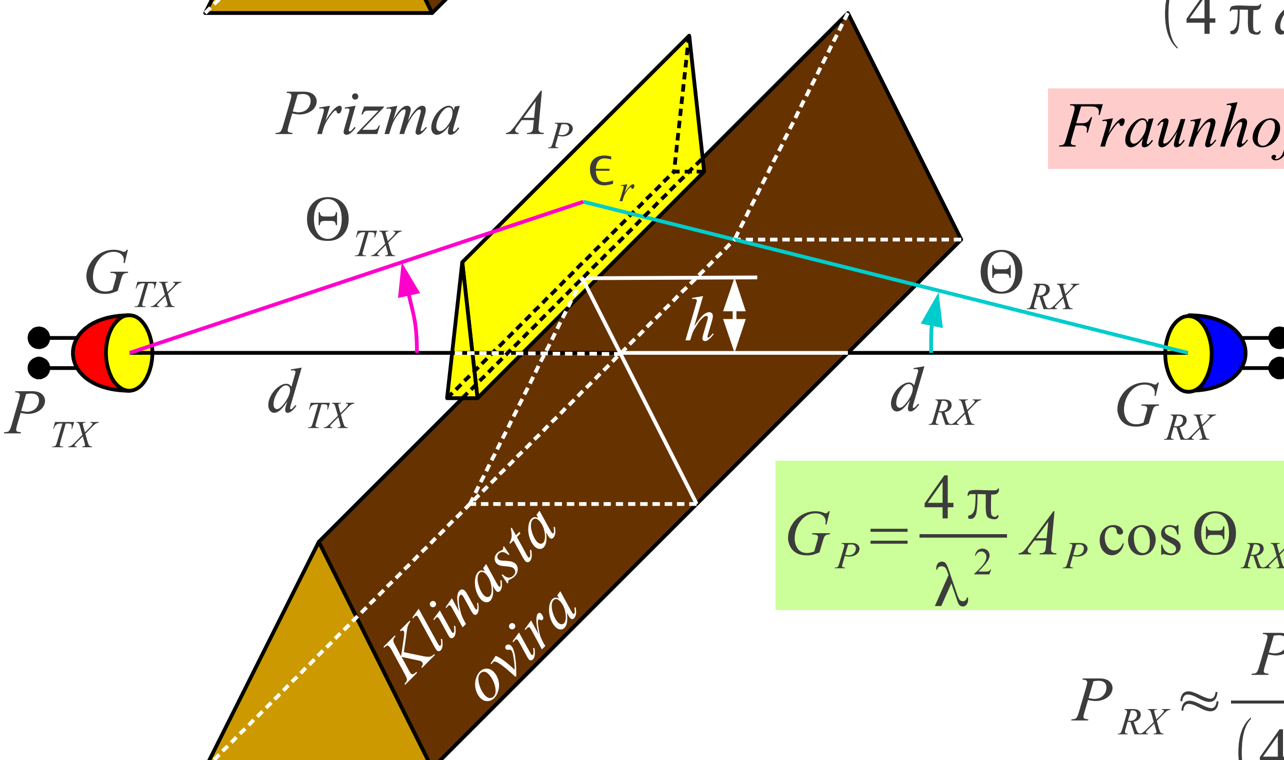
$$P_U\approx\frac{P_{TX}G_{TX}A_U\cos\Theta_{TX}}{4\pi d_{TX}^2}$$

$$G_U=\frac{4\pi}{\lambda^2}\frac{A_U\cos\Theta_{RX}}{\pi^2}$$

$$P_{RX}\approx P_U G_U G_{RX}\left(\frac{\lambda}{4\pi d_{RX}}\right)^2$$

$$P_{RX}\approx\frac{P_{TX}G_{TX}G_{RX}}{(4\pi d_{TX}d_{RX})^2}\left(\frac{A_U}{\pi}\right)^2\cos\Theta_{TX}\cos\Theta_{RX}$$

Fraunhofer $d_{TX}, d_{RX} > 2A_U/\lambda, 2A_P/\lambda$



$$P_P\approx\frac{P_{TX}G_{TX}A_P\cos\Theta_{TX}}{4\pi d_{TX}^2}$$

$$G_P=\frac{4\pi}{\lambda^2}A_P\cos\Theta_{RX}$$

$$P_{RX}\approx P_P G_P G_{RX}\left(\frac{\lambda}{4\pi d_{RX}}\right)^2$$

$$P_{RX}\approx\frac{P_{TX}G_{TX}G_{RX}}{(4\pi d_{TX}d_{RX})^2}A_P^2\cos\Theta_{TX}\cos\Theta_{RX}$$