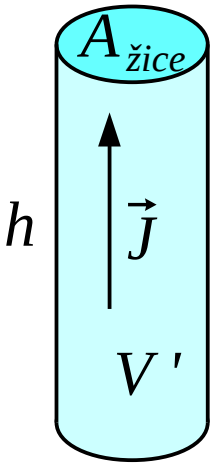
Žica

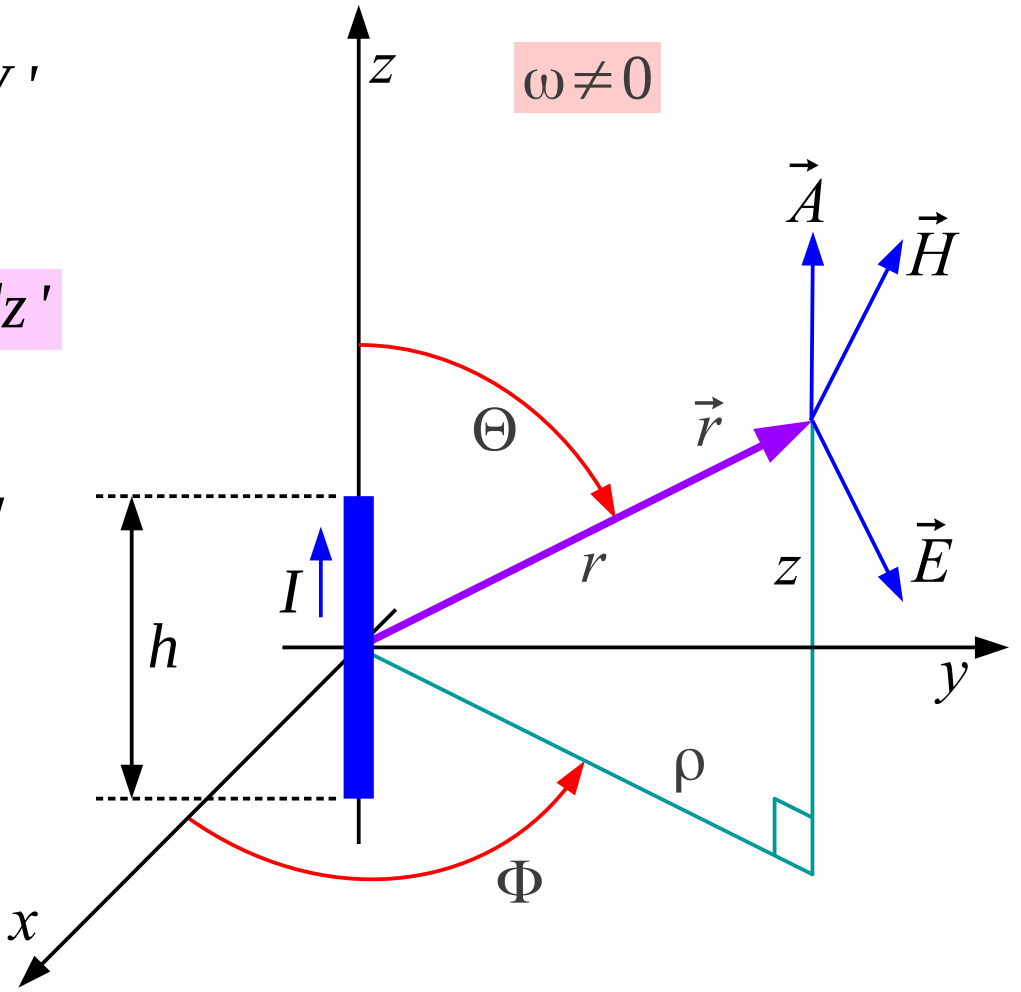


$$\vec{A}(\vec{r}) = \frac{\mu}{4\pi}\int_{V'} \vec{J}(\vec{r}\,')\frac{e^{-jk|\vec{r}-\vec{r}\,'|}}{|\vec{r}-\vec{r}\,'|}\,dV'$$

$$\vec{J}(\vec{r}\,') = \vec{1}_z \frac{I}{A_{žice}}$$

$$dV' = A_{žice}\,dz'$$

$$\vec{A}(\vec{r}) = \frac{\mu}{4\pi}\int_{-h/2}^{h/2} \vec{1}_z I \frac{e^{-jk|\vec{r}-\vec{r}\,'|}}{|\vec{r}-\vec{r}\,'|}\,dz'$$



Poenostavitve:

(1) $h \ll r \;\rightarrow\; \dfrac{1}{|\vec{r}-\vec{r}\,'|} \approx \dfrac{1}{r}$

(2) $h \ll \lambda = \dfrac{2\pi}{k} \;\rightarrow\; e^{-jk|\vec{r}-\vec{r}\,'|} \approx e^{-jkr}$

$$\vec{A}(\vec{r}) = \vec{1}_z \frac{\mu I h}{4\pi}\frac{e^{-jkr}}{r} = \left(\vec{1}_r \cos\Theta - \vec{1}_\Theta \sin\Theta\right)\frac{\mu I h}{4\pi}\frac{e^{-jkr}}{r}$$

$$\vec{1}_z = \vec{1}_r \cos\Theta - \vec{1}_\Theta \sin\Theta$$

$$\vec{H}(\vec{r}) = \frac{1}{\mu}\,\mathrm{rot}\,\vec{A}(\vec{r}) = \vec{1}_\Phi \frac{I h}{4\pi} e^{-jkr}\left(\frac{jk}{r} + \frac{1}{r^2}\right)\sin\Theta$$

Sevanje

Biot-Savart

<u>Tokovni element</u>

$$\vec{E}(\vec{r}) = \frac{1}{j\omega\epsilon}\,\mathrm{rot}\,\vec{H} = \frac{I\,h}{4\pi\,j\omega\epsilon}\,\mathrm{e}^{-jkr}\left[\vec{1}_r\left(\frac{jk}{r^2}+\frac{1}{r^3}\right)2\cos\Theta + \vec{1}_\Theta\left(-\frac{k^2}{r}+\frac{jk}{r^2}+\frac{1}{r^3}\right)\sin\Theta\right]$$

Zveznost toka / elektrine

$$I = j\omega Q$$

$$\vec{E}(\vec{r}) = \frac{Q\,h}{4\pi\epsilon}\,\mathrm{e}^{-jkr}\left[\vec{1}_r\left(\frac{jk}{r^2}+\frac{1}{r^3}\right)2\cos\Theta + \vec{1}_\Theta\left(-\frac{k^2}{r}+\frac{jk}{r^2}+\frac{1}{r^3}\right)\sin\Theta\right]$$

Sevanje

Točkasti statični električni dipol

$$\frac{1}{\omega\epsilon} = \frac{1}{\omega\sqrt{\mu\epsilon}}\sqrt{\frac{\mu}{\epsilon}} = \frac{Z}{k}$$

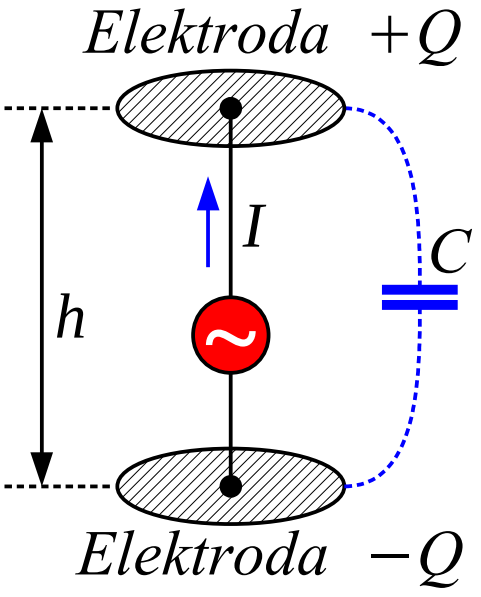
$$\vec{S}(\vec{r}) = \frac{1}{2}\,\vec{E}(\vec{r})\times\vec{H}(\vec{r})^* = \frac{|I|^2 h^2 Z}{32\pi^2 k}\left[\vec{1}_r\left(\frac{k^3}{r^2}-\frac{j}{r^5}\right)\sin^2\Theta + \vec{1}_\Theta\left(\frac{j\,k^2}{r^3}+\frac{j}{r^5}\right)2\cos\Theta\sin\Theta\right]$$

Sevanje

$$P = \lim_{r\to\infty}\oiint \vec{S}(\vec{r})\cdot\vec{1}_r\,r^2\sin\Theta\,d\Theta\,d\Phi = \frac{|I|^2 h^2 Z k^2}{12\pi}$$

$$R_s = \frac{2P}{|I|^2} = \frac{Z k^2 h^2}{6\pi} = \frac{2\pi Z}{3}\left(\frac{h}{\lambda}\right)^2$$

$$h \ll \lambda \;\rightarrow\; R_S \ll \frac{1}{\omega C}$$



Dinamični električni dipol

Tokovna zanka

$$\vec{A}(\vec{r}) = \frac{\mu}{4\pi}\int_{V'} \vec{J}(\vec{r}\,')\frac{e^{-jk|\vec{r}-\vec{r}\,'|}}{|\vec{r}-\vec{r}\,'|}\,dV'$$

$$|\vec{r}-\vec{r}\,'| = \sqrt{\begin{array}{c}(r\sin\Theta\cos\Phi - a\cos\Phi')^2 + \\ +(r\sin\Theta\sin\Phi - a\sin\Phi')^2 + (r\cos\Theta)^2\end{array}}$$

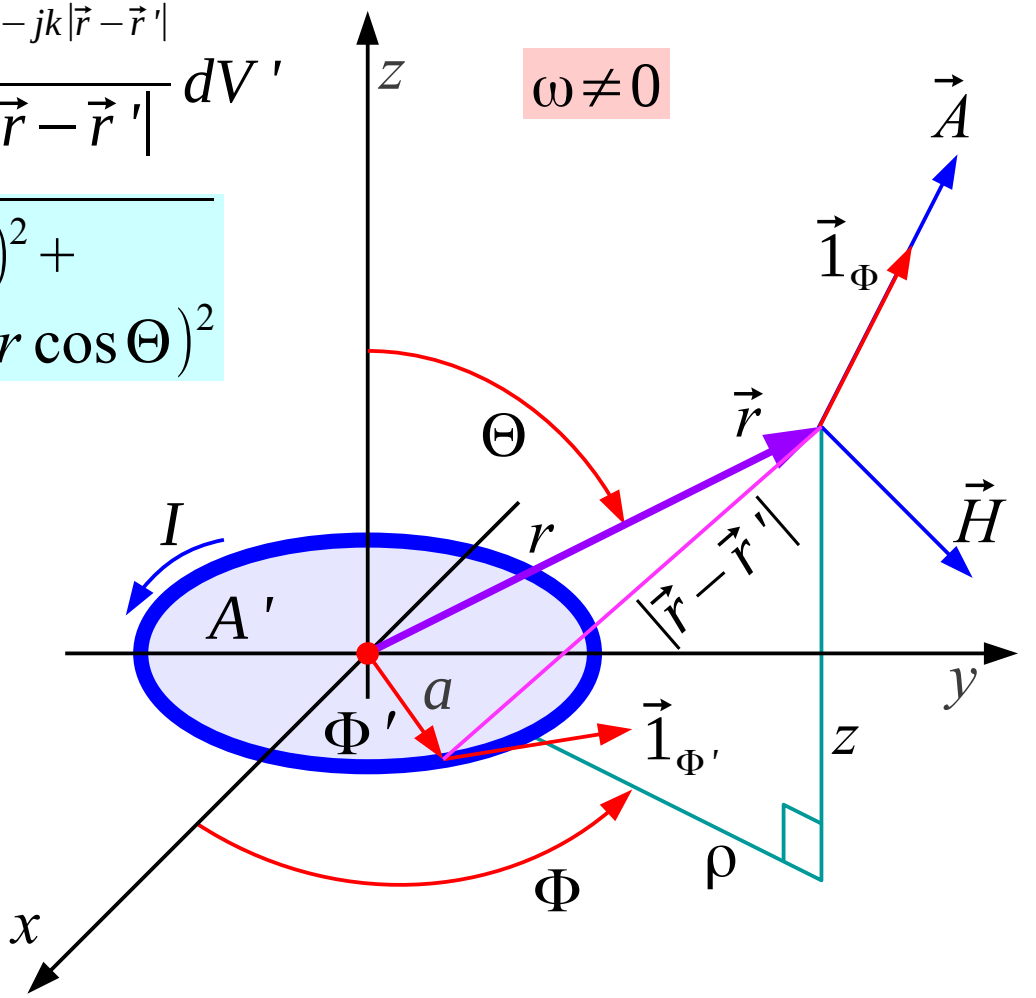
$$\vec{J}(\vec{r}\,') = \vec{1}_{\Phi'}\frac{I}{A_{žice}}$$

$$dV' = A_{žice}\,a\,d\Phi'$$

$$\vec{A}(\vec{r}) = \frac{\mu}{4\pi}\int_0^{2\pi} \vec{1}_{\Phi'} I\frac{e^{-jk|\vec{r}-\vec{r}\,'|}}{|\vec{r}-\vec{r}\,'|}\,a\,d\Phi'$$

$$\vec{1}_{\Phi'} = -\vec{1}_x\sin\Phi' + \vec{1}_y\cos\Phi'$$

$$-\vec{1}_x\sin\Phi + \vec{1}_y\cos\Phi = \vec{1}_\Phi$$



Površina zanke

$$A' = \pi a^2$$

Poenostavitve:

(1) $a \ll r \;\rightarrow\; \dfrac{1}{|\vec{r}-\vec{r}\,'|} \approx \dfrac{1}{r}\left[1 + \dfrac{a}{r}\sin\Theta\cos(\Phi-\Phi')\right]$

(2) $a \ll \lambda \;\rightarrow\; e^{-jk|\vec{r}-\vec{r}\,'|} \approx e^{-jkr}\left[1 + jka\sin\Theta\cos(\Phi-\Phi')\right]$

$$\vec{A}(\vec{r}) = \vec{1}_\Phi\frac{\mu}{4\pi} I(\pi a^2)e^{-jkr}\left(\frac{jk}{r}+\frac{1}{r^2}\right)\sin\Theta = \vec{1}_\Phi\frac{\mu}{4\pi} I\,A'\,e^{-jkr}\left(\frac{jk}{r}+\frac{1}{r^2}\right)\sin\Theta$$

$$\vec{H}(\vec{r}) = \frac{1}{\mu}\,\mathrm{rot}\,\vec{A}(\vec{r}) = \frac{IA'}{4\pi}\,e^{-jkr}\left[\vec{1}_r\left(\frac{jk}{r^2}+\frac{1}{r^3}\right)2\cos\Theta + \vec{1}_\Theta\left(-\frac{k^2}{r}+\frac{jk}{r^2}+\frac{1}{r^3}\right)\sin\Theta\right]$$

Sevanje

Točkasti statični magnetni dipol

$$\rho(\vec{r}\,') = 0 \;\rightarrow\; grad\,V(\vec{r}) = 0 \;\rightarrow\; \vec{E}(\vec{r}) = -j\omega\vec{A}(\vec{r})$$

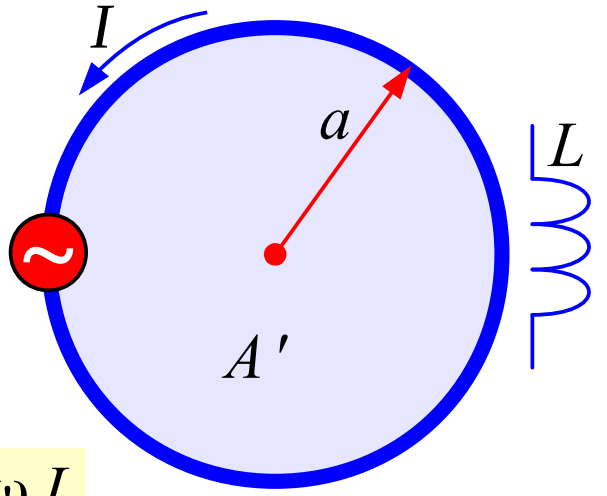
$$\omega\mu = \omega\sqrt{\mu\epsilon}\sqrt{\frac{\mu}{\epsilon}} = kZ$$

$$\vec{E}(\vec{r}) = -\vec{1}_\Phi\frac{j\omega\mu I A'}{4\pi}e^{-jkr}\left(\frac{jk}{r}+\frac{1}{r^2}\right)\sin\Theta = \vec{1}_\Phi\frac{ZIA'}{4\pi}e^{-jkr}\left(\frac{k^2}{r}-\frac{jk}{r^2}\right)\sin\Theta$$

$$\vec{S}(\vec{r}) = \frac{|I|^2(A')^2 Z}{32\pi}\left[\vec{1}_r\left(\frac{k^4}{r^2}+\frac{jk}{r^5}\right)\sin^2\Theta - \vec{1}_\Theta\left(\frac{jk^3}{r^3}+\frac{jk}{r^5}\right)2\cos\Theta\sin\Theta\right]$$

Sevanje

$$P = \oiint_{r\to\infty}\vec{S}(\vec{r})\cdot\vec{1}_r r^2\sin\Theta\,d\Theta\,d\Phi = \frac{|I|^2(A')^2 Z k^4}{12\pi}$$



$$R_s = \frac{2P}{|I|^2} = \frac{Zk^4(A')^2}{6\pi} = \frac{8\pi^3 Z}{3}\left(\frac{A'}{\lambda^2}\right)^2$$

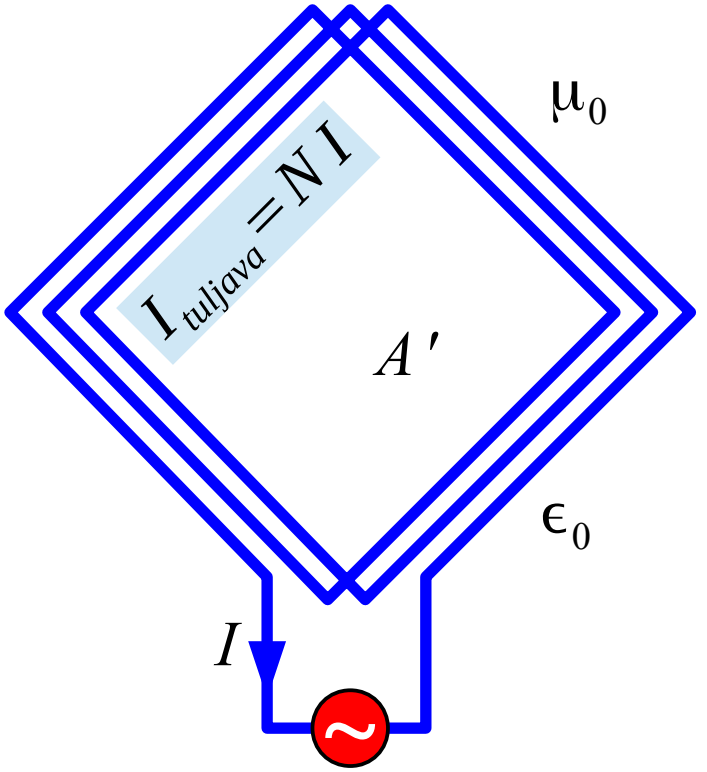
Dinamični magnetni dipol

$$\sqrt{A'} \ll \lambda \;\rightarrow\; R_S \ll \omega L$$

$$R_s = \frac{Z k^4 (N A')^2}{6\pi} = \frac{8\pi^3 Z}{3}\left(\frac{N A'}{\lambda^2}\right)^2$$

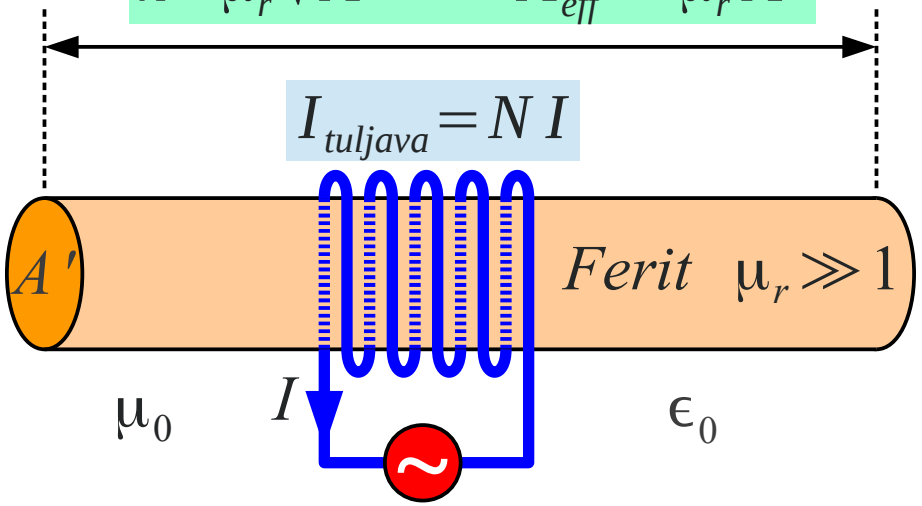
$f \approx 300\text{kHz}$
$A' \approx 1\text{m}^2$
$N \approx 10$

Zrak
$Z_0 = \sqrt{\frac{\mu_0}{\epsilon_0}} \approx 377\,\Omega$
$\lambda = c_0 / f = 1\text{km}$
$R_S \approx 3.1\,\mu\Omega$



Okvirna antena ~1930

$h > \mu_r \sqrt{A'} \;\rightarrow\; A_{eff}' \approx \mu_r A'$



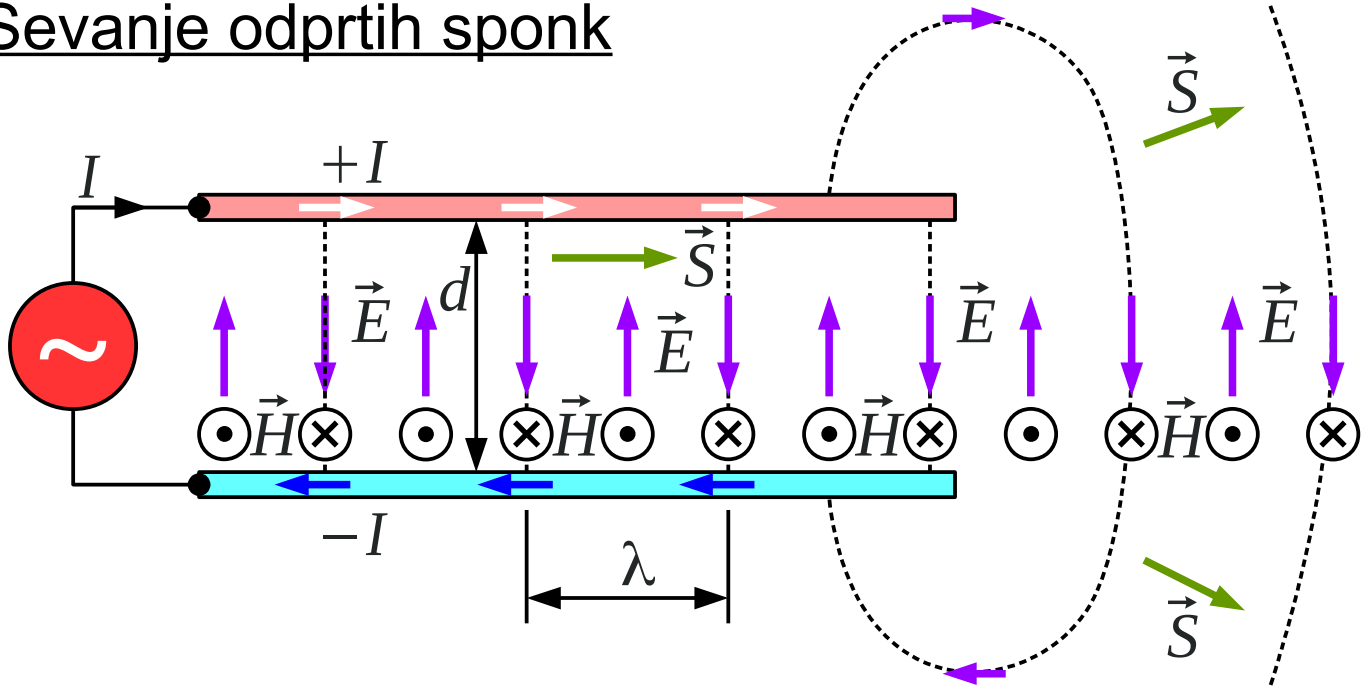
$$R_s = \frac{Z k^4 (\mu_r N A')^2}{6\pi} = \frac{8\pi^3 Z}{3}\left(\frac{\mu_r N A'}{\lambda^2}\right)^2$$

$f \approx 1\text{MHz}$
$A' \approx 1\text{cm}^2$
$h \approx 20\text{cm}$
$\mu_r \approx 100$
$N \approx 30$

Zrak
$Z_0 = \sqrt{\frac{\mu_0}{\epsilon_0}} \approx 377\,\Omega$
$\lambda = c_0 / f = 300\text{m}$
$R_S \approx 0.35\,\mu\Omega$

Feritna antena ~1970

Sevanje odprtih sponk

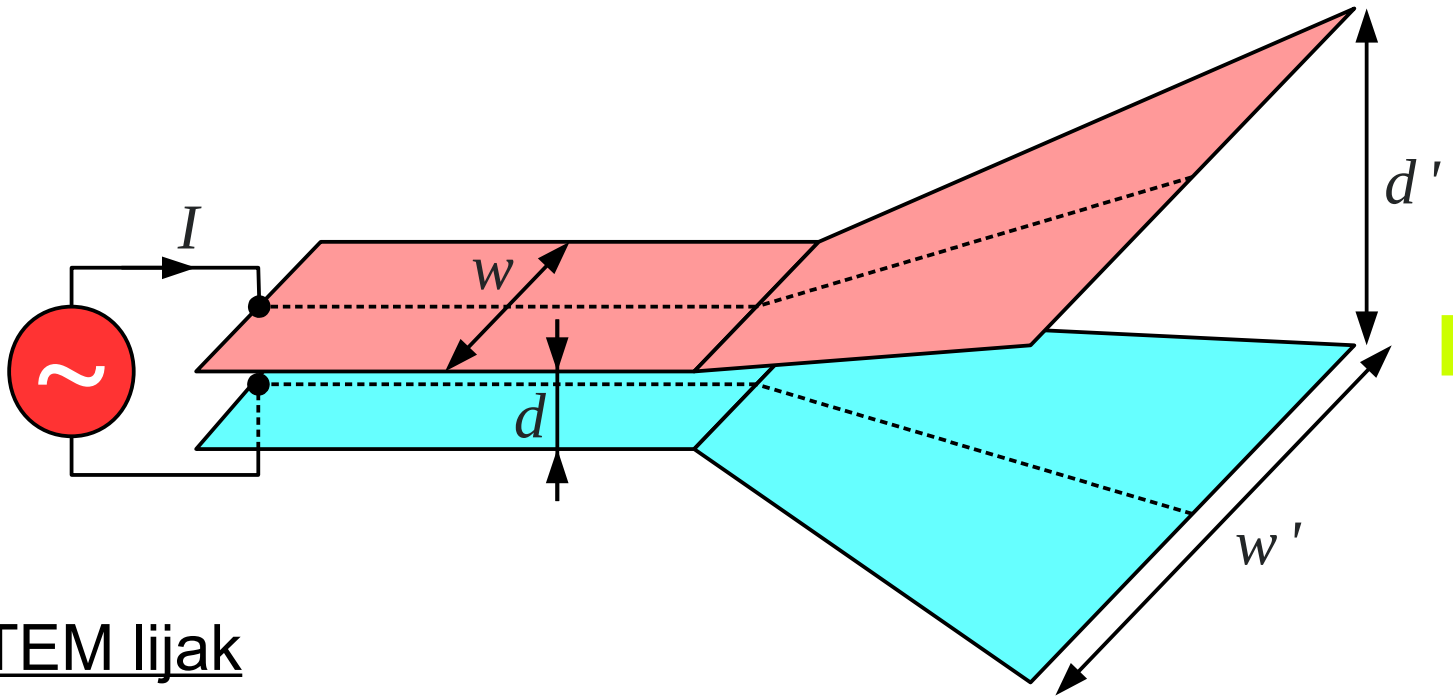


$d \ll \lambda \;\rightarrow\; \Gamma \approx +1$

$d \approx \lambda/2 \;\rightarrow\; |\Gamma| \approx 0.3$

$d \gg \lambda \;\rightarrow\; \Gamma \approx 0$

Trakasti dvovod $Z_K \approx \frac{d}{w}\sqrt{\frac{\mu_0}{\epsilon_0}}$



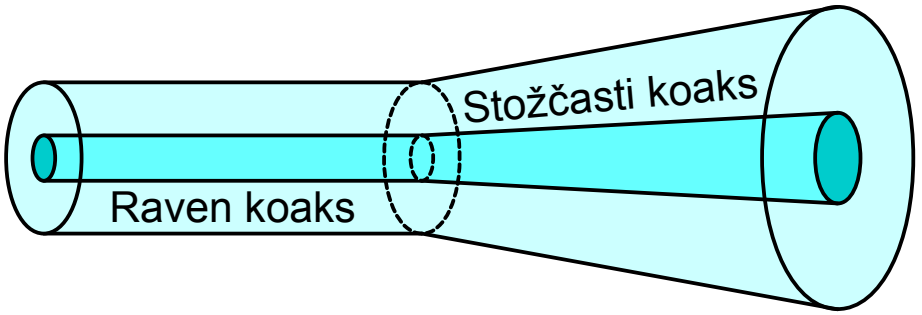
Sevanje

$Z_K \approx \frac{d}{w}\sqrt{\frac{\mu_0}{\epsilon_0}} = \frac{d'}{w'}\sqrt{\frac{\mu_0}{\epsilon_0}}$

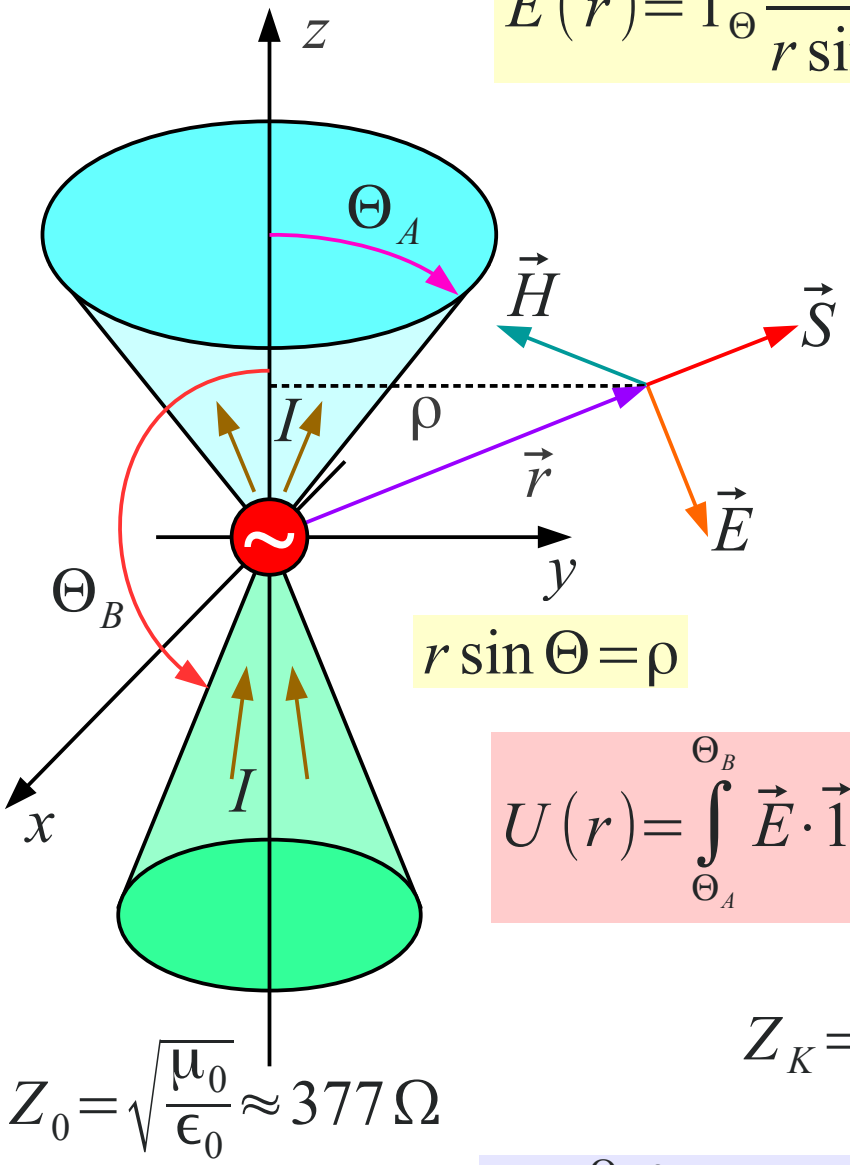
TEM lijak

Stožčasti vod

$$C\,[\mathrm{V}] \equiv konstanta$$



$$\vec{E}(\vec{r}) = \vec{1}_\Theta \frac{C}{r \sin\Theta} e^{\mp jkr}$$



$$r \sin\Theta = \rho$$

$$\vec{H}(\vec{r}) = \frac{j}{\omega\mu} \mathrm{rot}\, \vec{E}(\vec{r}) = \pm \vec{1}_\Phi \frac{C/Z_0}{r \sin\Theta} e^{\mp jkr}$$

$$\vec{S}(\vec{r}) = \frac{1}{2} \vec{E} \times \vec{H}^* = \pm \vec{1}_r \frac{|C|^2}{2 Z_0} \left(\frac{1}{r \sin\Theta} \right)^2$$

$$I(r) = \int_0^{2\pi} \vec{H} \cdot \vec{1}_\Phi r \sin\Theta \, d\Phi = \pm \frac{2\pi C}{Z_0} e^{\mp jkr}$$

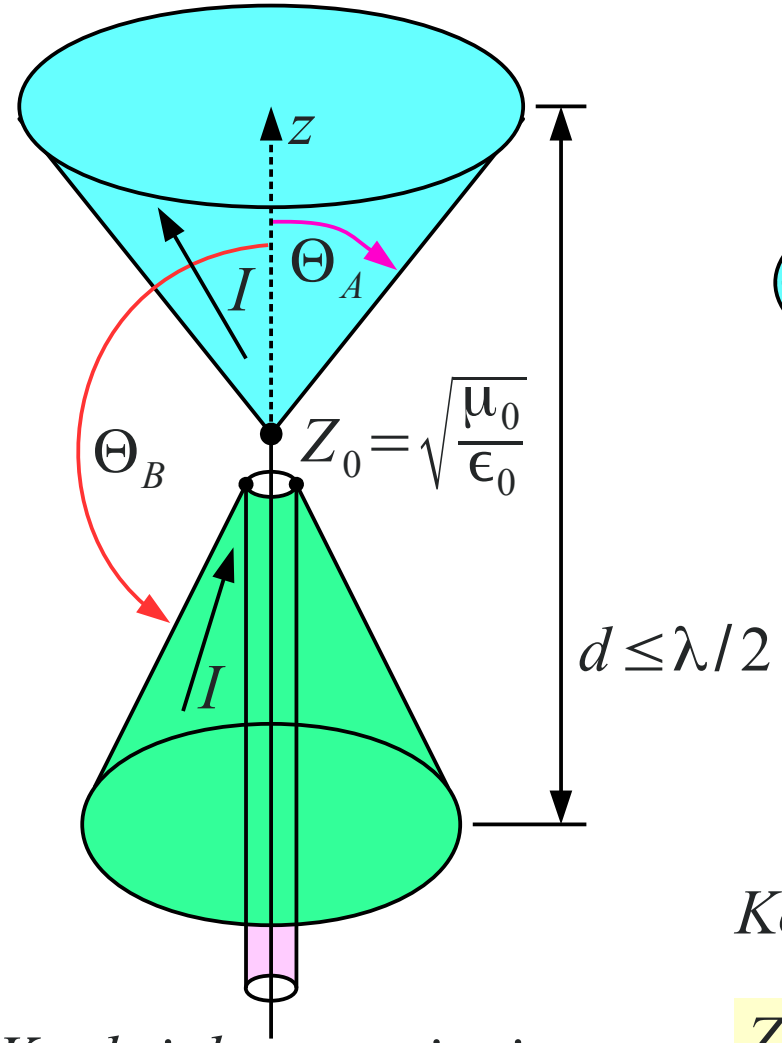
$$U(r) = \int_{\Theta_A}^{\Theta_B} \vec{E} \cdot \vec{1}_\Theta r \, d\Theta = C e^{\mp jkr} \int_{\Theta_A}^{\Theta_B} \frac{d\Theta}{\sin\Theta} = C e^{\mp jkr} \ln \left(\frac{\mathrm{tg}(\Theta_B/2)}{\mathrm{tg}(\Theta_A/2)} \right)$$

$$Z_K = \pm \frac{U}{I} = \frac{Z_0}{2\pi} \ln \left(\frac{\mathrm{tg}(\Theta_B/2)}{\mathrm{tg}(\Theta_A/2)} \right) \approx 60\,\Omega \ln \left(\frac{\mathrm{tg}(\Theta_B/2)}{\mathrm{tg}(\Theta_A/2)} \right)$$

$$Z_0 = \sqrt{\frac{\mu_0}{\epsilon_0}} \approx 377\,\Omega$$

$$P = \int_{\Theta_A}^{\Theta_B} \int_0^{2\pi} \vec{S} \cdot \vec{1}_r r^2 \sin\Theta \, d\Theta \, d\Phi = \frac{U I^*}{2} = \pm \frac{\pi |C|^2}{Z_0} \ln \left(\frac{\mathrm{tg}(\Theta_B/2)}{\mathrm{tg}(\Theta_A/2)} \right)$$

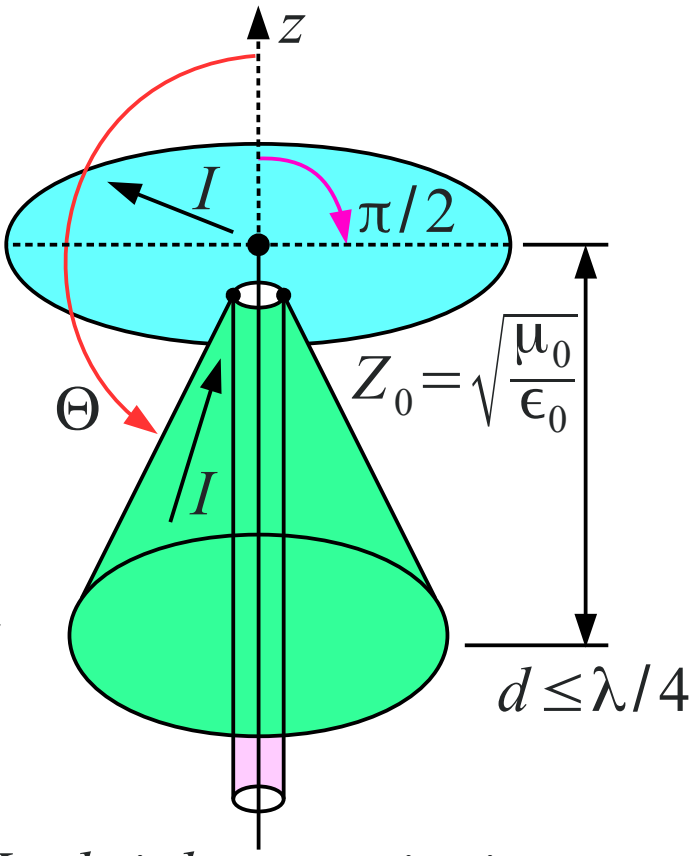
Bikonična antena



Koaksialno napajanje

$$Z_K \approx 60\,\Omega \ln\left(\frac{\mathrm{tg}\left(\Theta_B/2\right)}{\mathrm{tg}\left(\Theta_A/2\right)}\right)$$

Discone antena



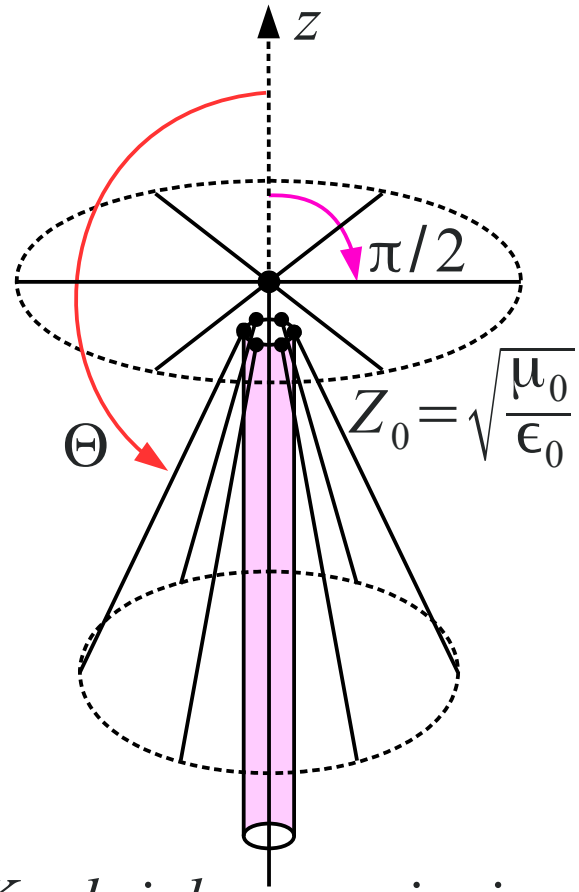
Koaksialno napajanje

$$Z_K \approx 60\,\Omega \ln\left(\mathrm{tg}\left(\Theta/2\right)\right)$$

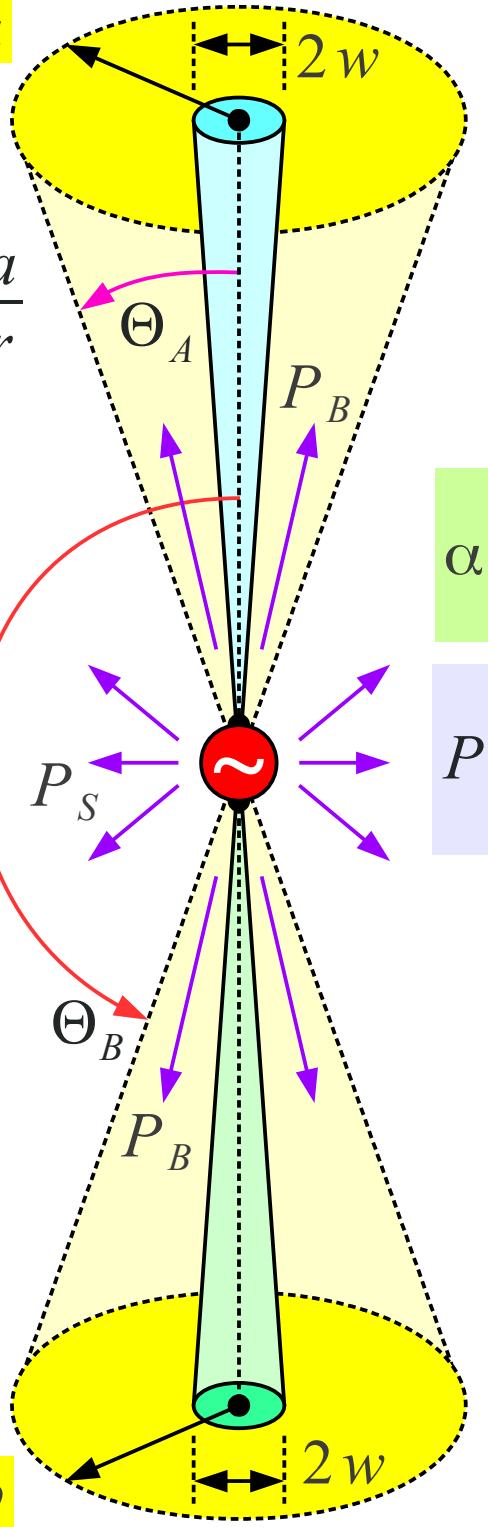
$$\Theta \approx 2\,\mathrm{arctg}\left(e^{Z/60\,\Omega}\right)$$

$$Z_K = 50\,\Omega \;\rightarrow\; \Theta \approx 133^\circ$$

Discone iz palčk



Koaksialno napajanje



$\lambda/2\pi = a$

$w \ll a = \lambda/2\pi$

$\sin\Theta_W = \frac{w}{r}$

$\sin\Theta_A = \frac{a}{r}$

Točna rešitev $\vec{E}(\vec{r}) = \vec{1}_\Theta \frac{C}{r\sin\Theta} e^{\mp jkr}$

$\alpha = \pm\frac{\pi|C|^2}{Z_0}$

Zgled $w = 0.001\,\lambda$ $r = \lambda/2$

$$P_S = \alpha \ln\left(\frac{\mathrm{tg}(\Theta_B/2)}{\mathrm{tg}(\Theta_A/2)}\right) = -2\alpha \ln \mathrm{tg}(\Theta_A/2) \approx 3.623\,\alpha$$

$$P_B = \alpha\left[\ln\left(\frac{\mathrm{tg}(\Theta_A/2)}{\mathrm{tg}(\Theta_W/2)}\right) + \ln\left(\frac{\mathrm{tg}((\pi-\Theta_W)/2)}{\mathrm{tg}(\Theta_B/2)}\right)\right] =$$

$$= 2\alpha \ln\left(\frac{\mathrm{tg}(\Theta_A/2)}{\mathrm{tg}(\Theta_W/2)}\right) \approx 10.19\,\alpha$$

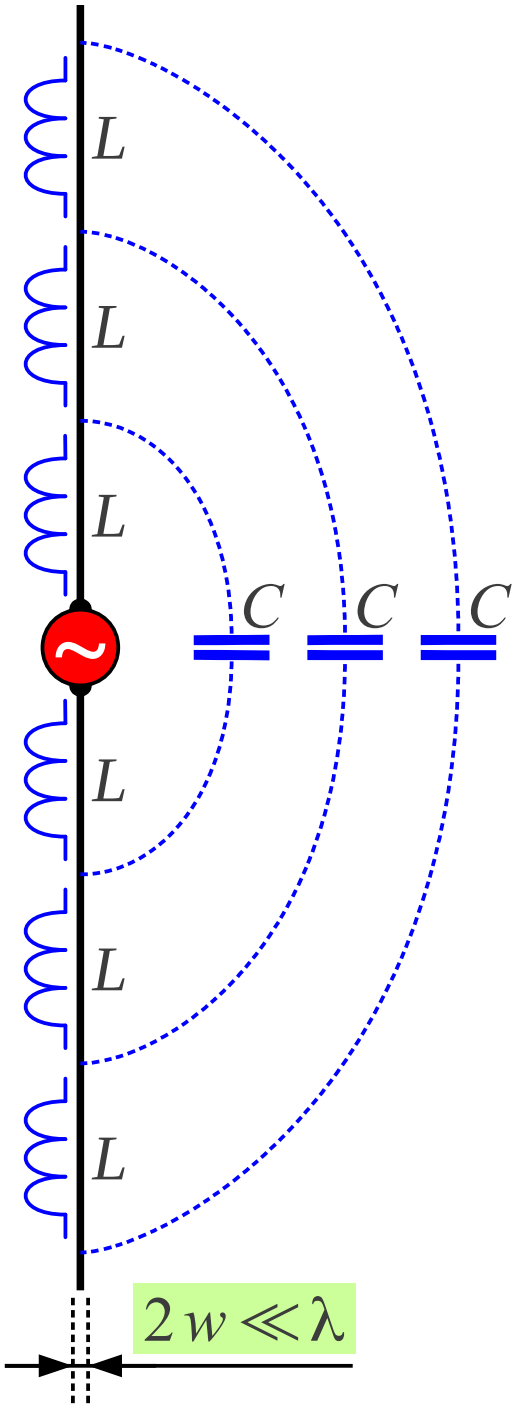
$\sin\Theta_B = \frac{b}{r}$

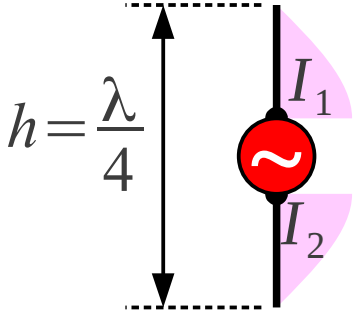
$\Theta_B = \pi - \Theta_A$

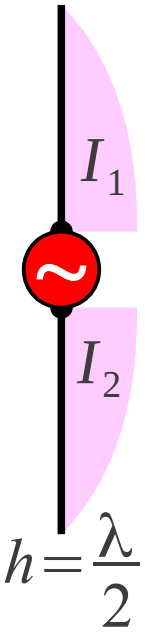
$\sin(\pi - \Theta_W) = \frac{w}{r}$

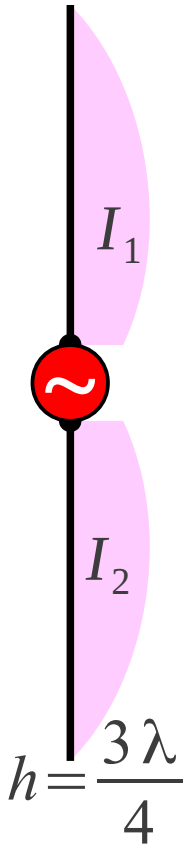
$\lambda/2\pi = b$

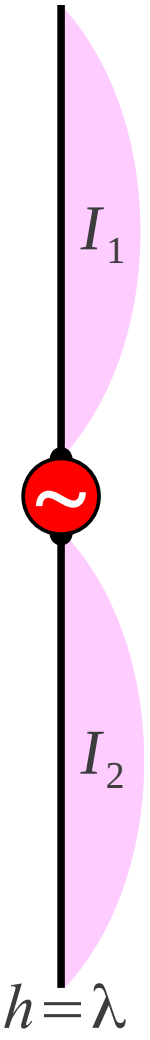
Vitka stožca

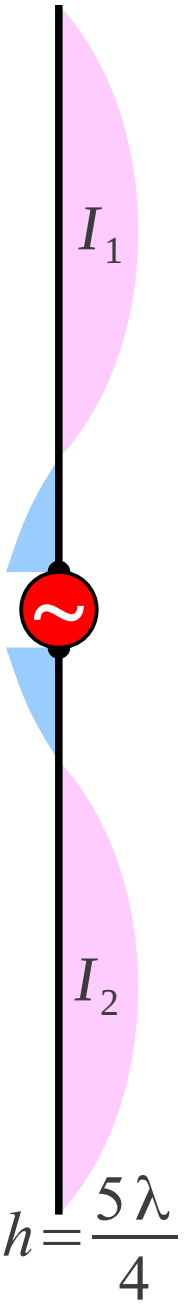


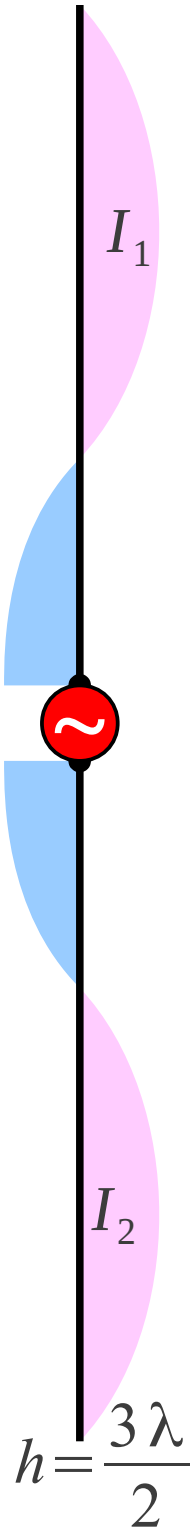


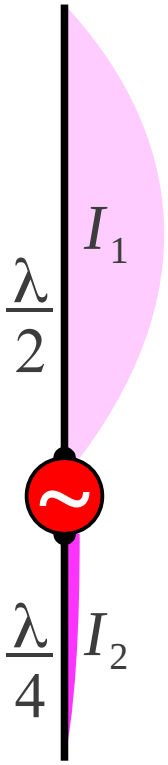


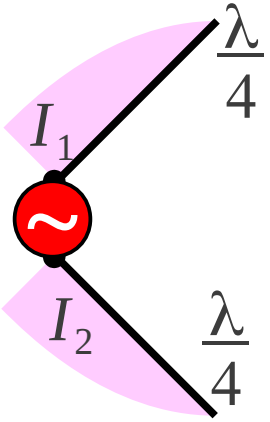


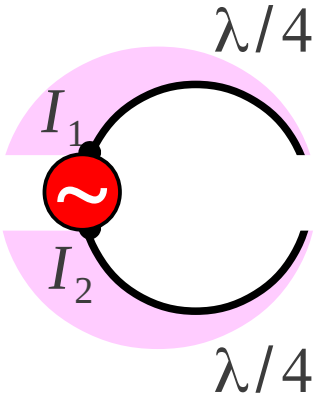






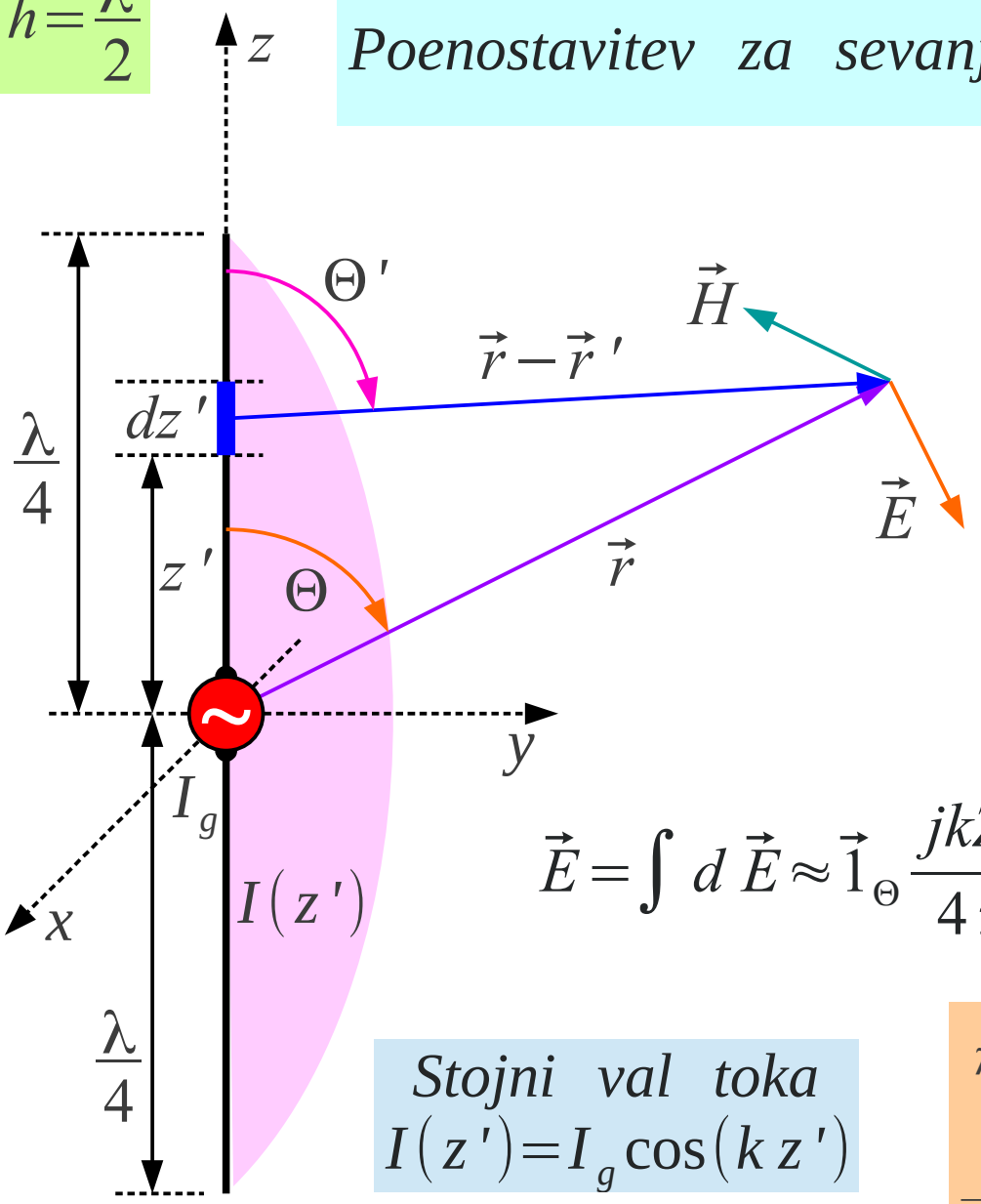






Stojni val na tankih žičnih dipolih

$h = \frac{\lambda}{2}$



Poenostavitev za sevanje $d\vec{E} \approx \vec{1}_{\Theta'} \frac{jkZ_0}{4\pi} I(z')\,dz' \frac{e^{-jk|\vec{r}-\vec{r}\,'|}}{|\vec{r}-\vec{r}\,'|} \sin\Theta'$

$$|\vec{r}-\vec{r}\,'| = \sqrt{r^2 + z'^2 - 2r\,z'\cos\Theta}$$

$r \gg h \;\rightarrow\; |\vec{r}-\vec{r}\,'| \approx r - z'\cos\Theta$

Daljnje polje $r \gg \frac{2h^2}{\lambda}$ $\quad \vec{1}_{\Theta'} \approx \vec{1}_{\Theta}$

$$\frac{1}{|\vec{r}-\vec{r}\,'|} \approx \frac{1}{r} \qquad \sin\Theta' \approx \sin\Theta$$

$$e^{-jk|\vec{r}-\vec{r}\,'|} \approx e^{-jkr}\, e^{jkz'\cos\Theta}$$

$$\vec{E} = \int d\vec{E} \approx \vec{1}_{\Theta} \frac{jkZ_0}{4\pi} I_g \frac{e^{-jkr}}{r} \sin\Theta \int_{-\lambda/4}^{\lambda/4} \cos(k\,z')\, e^{jkz'\cos\Theta}\, dz'$$

Stojni val toka
$I(z') = I_g \cos(k\,z')$

$$\int_{-\lambda/4}^{\lambda/4} \cos(kz')\, e^{jkz'\cos\Theta}\, dz' = \frac{2\cos\left(\frac{\pi}{2}\cos\Theta\right)}{k\sin^2\Theta}$$

$$Z_0 = \sqrt{\frac{\mu_0}{\epsilon_0}} \approx 377\,\Omega$$

$$\vec{E} \approx \vec{1}_{\Theta} \frac{jZ_0}{2\pi} I_g \frac{e^{-jkr}}{r} \frac{\cos\left(\frac{\pi}{2}\cos\Theta\right)}{\sin\Theta}$$

Polvalovni dipol

$$\vec{S} = \vec{1}_r \frac{|\vec{E}|^2}{2 Z_0} = \vec{1}_r \frac{Z_0}{8\pi^2} |I_g|^2 \frac{1}{r^2} \left[\frac{\cos\left(\frac{\pi}{2}\cos\Theta\right)}{\sin\Theta} \right]^2$$

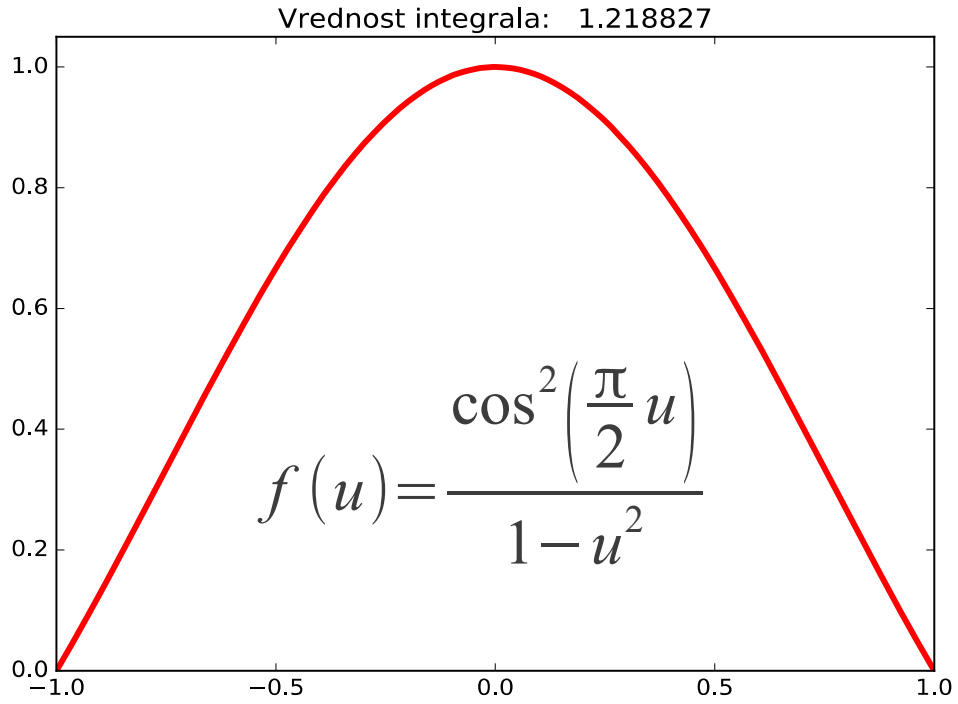
$$\int_0^{2\pi} d\Phi = 2\pi$$

$$P = \int_0^{\pi} \int_0^{2\pi} \vec{S} \cdot \vec{1}_r r^2 \sin\Theta \, d\Theta \, d\Phi = \frac{Z_0}{4\pi} |I_g|^2 \int_0^{\pi} \left[\frac{\cos\left(\frac{\pi}{2}\cos\Theta\right)}{\sin\Theta} \right]^2 \sin\Theta \, d\Theta$$

$$I_{\lambda/2} = \int_0^{\pi} \left[\frac{\cos\left(\frac{\pi}{2}\cos\Theta\right)}{\sin\Theta} \right]^2 \sin\Theta \, d\Theta = \int_{-1}^{1} \frac{\cos^2\left(\frac{\pi}{2}u\right)}{1-u^2} du \approx 1.218827$$

$$Z_0 = \sqrt{\frac{\mu_0}{\epsilon_0}} \approx 377\,\Omega \approx 120\,\pi\,\Omega$$

$$R_S = \frac{2P}{|I_g|^2} = \frac{Z_0}{2\pi} I_{\lambda/2} \approx 60\,\Omega\, I_{\lambda/2} \approx 73.1\,\Omega$$



Upornost polvalovnega dipola

$$h=\frac{\lambda}{2} \;\rightarrow\; F(\Theta,\Phi)=\frac{\cos\left(\frac{\pi}{2}\cos\Theta\right)}{\sin\Theta}$$

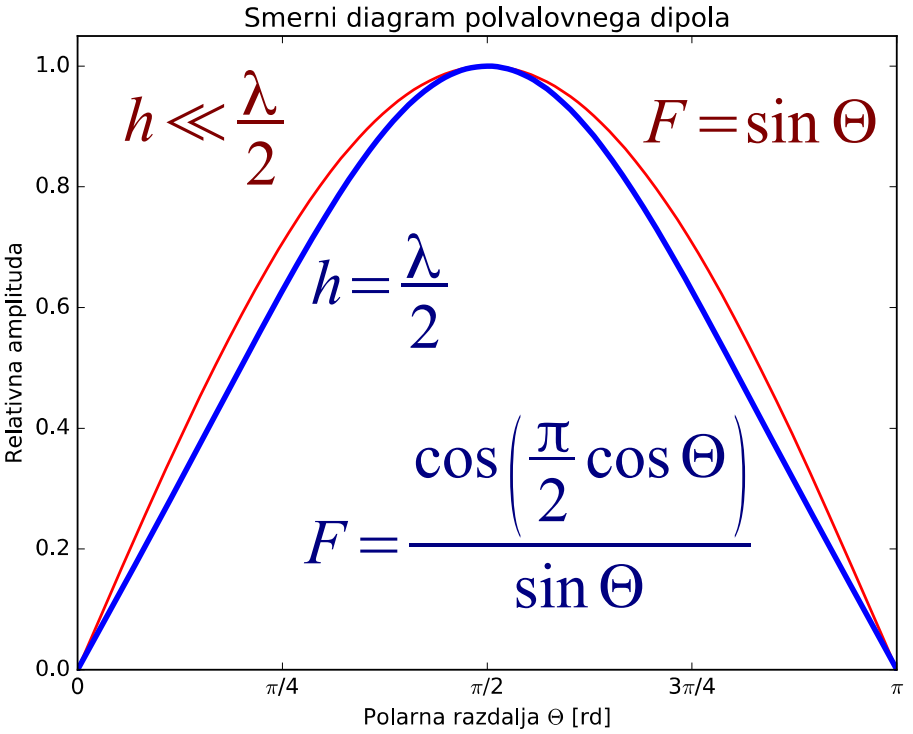
$$D=\frac{4\pi\left|F\left(\Theta_{MAX},\Phi_{MAX}\right)\right|^2}{\oiint_{4\pi}\left|F(\Theta,\Phi)\right|^2 d\Omega}$$

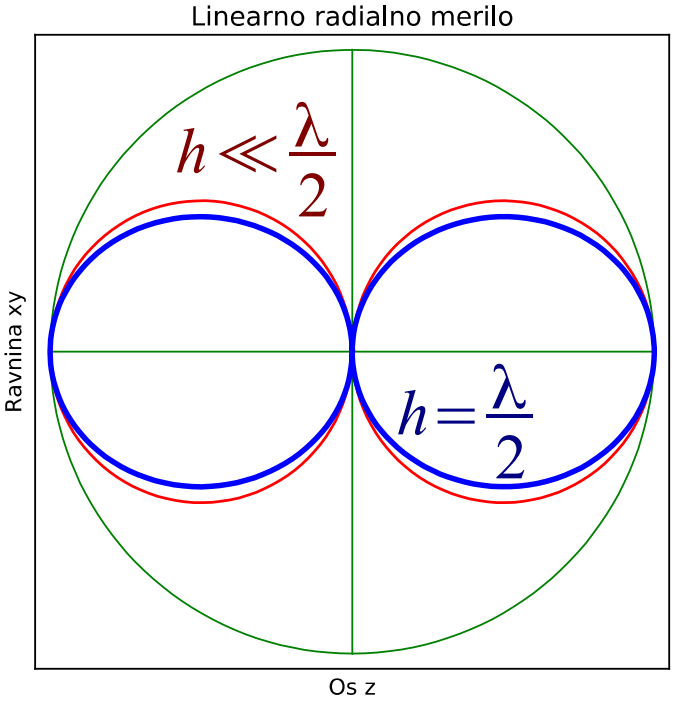
$$F\left(\Theta_{MAX}=\pi/2\right)=1$$

$$D=\frac{4\pi}{\int_0^{\pi}\int_0^{2\pi}\left[\frac{\cos\left(\frac{\pi}{2}\cos\Theta\right)}{\sin\Theta}\right]^2 \sin\Theta\, d\Theta\, d\Phi}$$

$$D=\frac{4\pi}{2\pi I_{\lambda/2}}=\frac{2}{1.218827}=1.640922$$

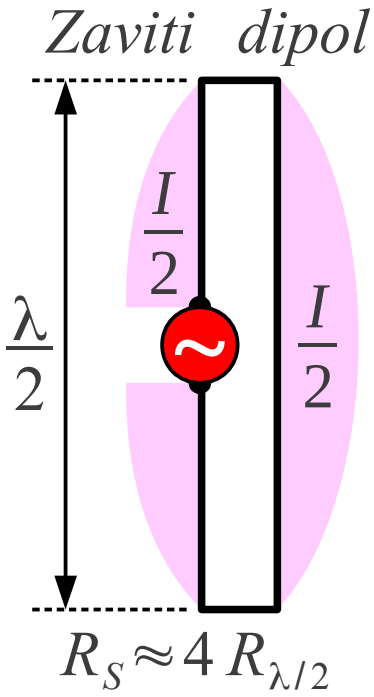
$$D_{\mathrm{dBi}}=10\log_{10}1.640922=2.150879\mathrm{dBi}$$

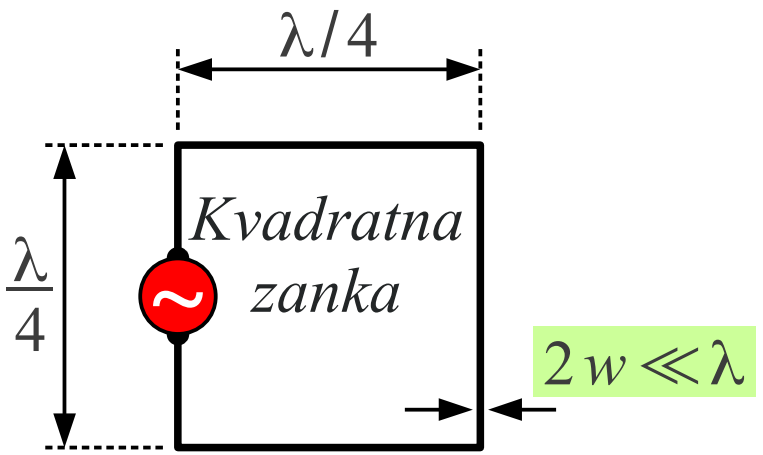


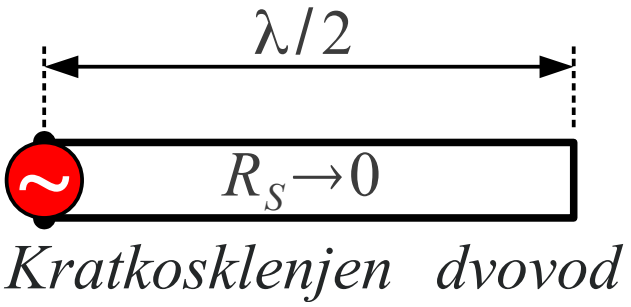


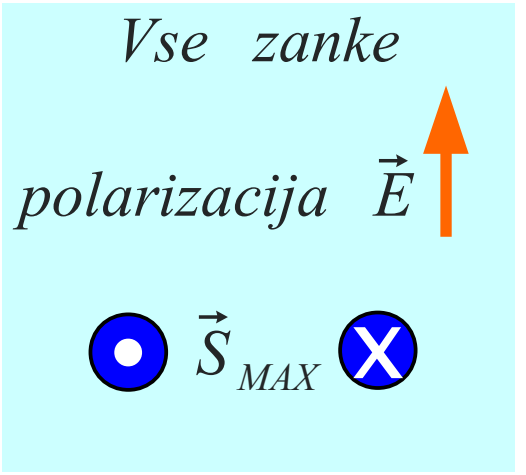
Smernost polvalovnega dipola

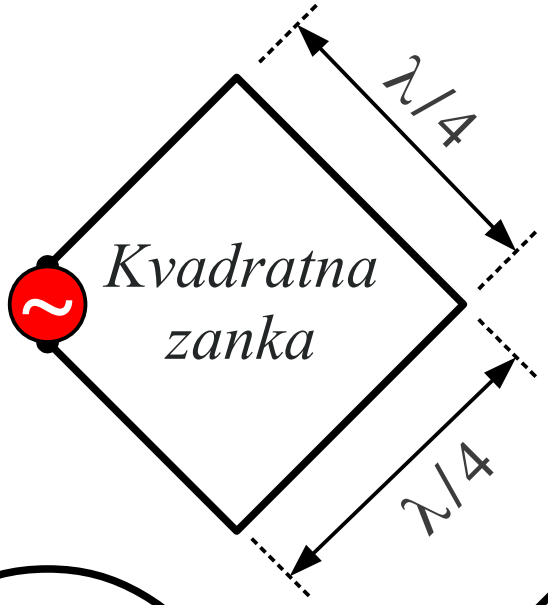
Enovalovne zanke

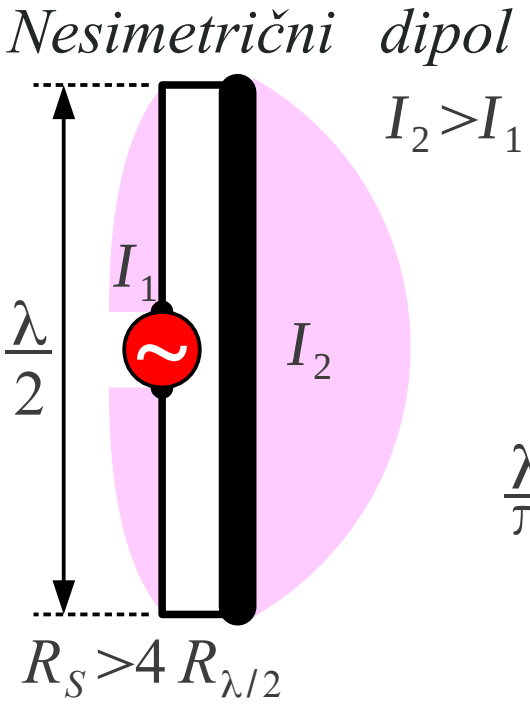


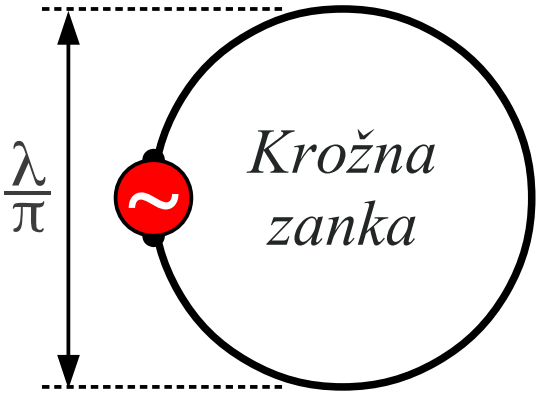


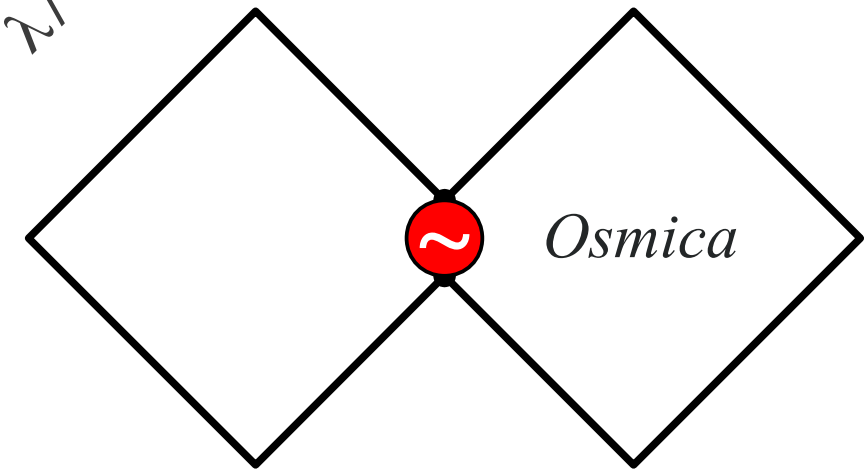




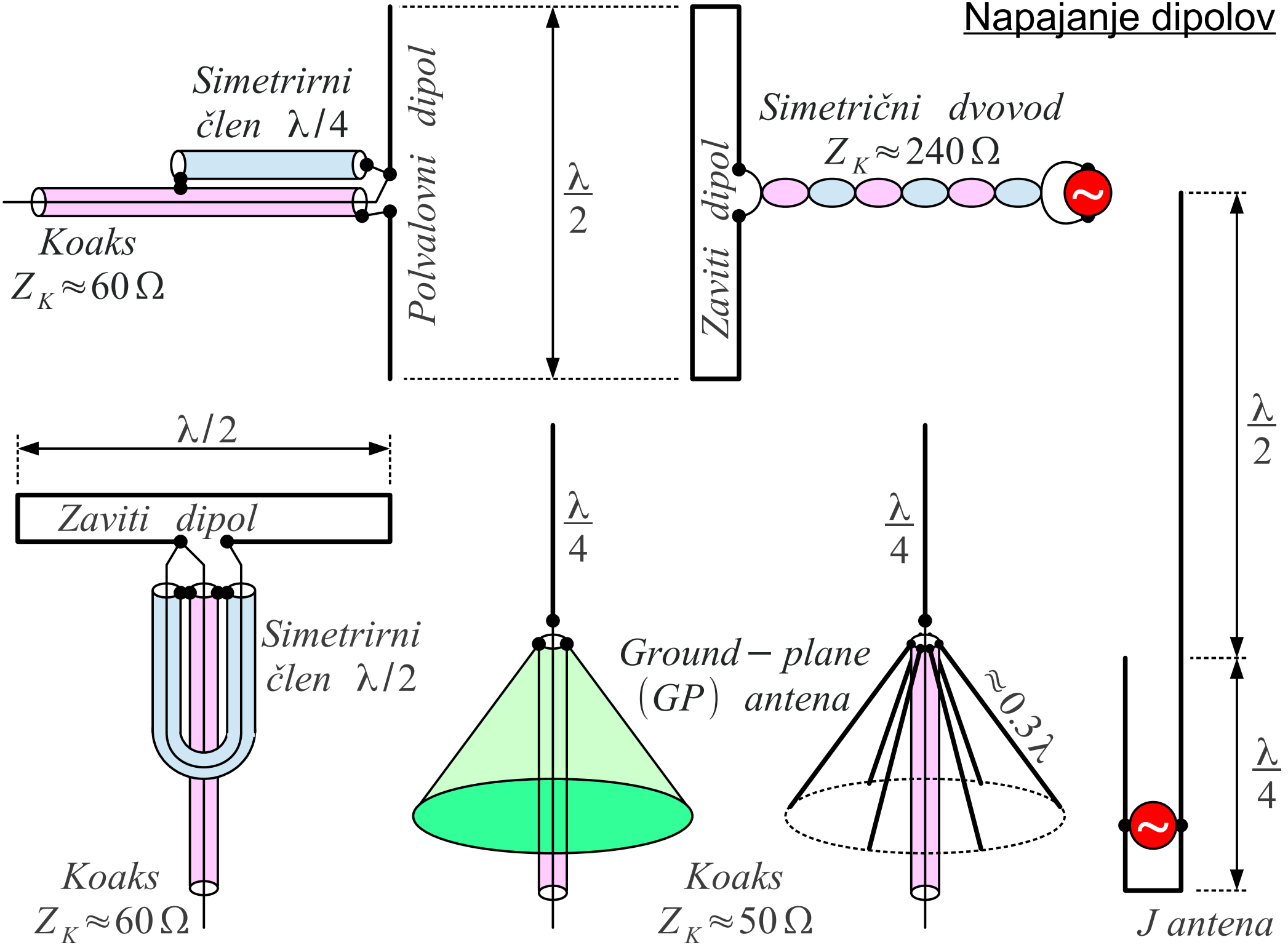








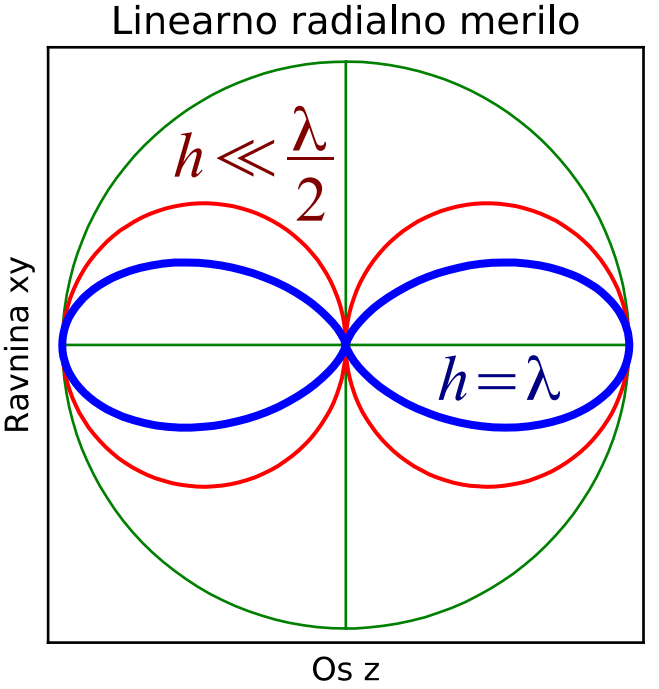
Napajanje dipolov



Stojni val toka

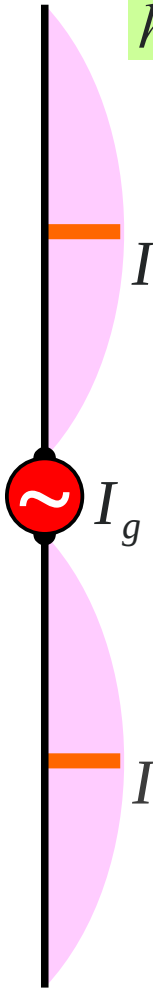
$$I(z') = I_{MAX}\left|\sin(k z')\right|$$

$$\vec{E} = \vec{E}_{\lambda/2}\, 2\cos\left(\frac{\pi}{2}\cos\Theta\right)$$



$h = \lambda$

$$\vec{E} \approx \vec{1}_\Theta \frac{jZ_0}{\pi} I_{MAX} \frac{e^{-jkr}}{r} \frac{\cos^2\left(\frac{\pi}{2}\cos\Theta\right)}{\sin\Theta}$$



$$F(\Theta,\Phi) = \frac{\cos^2\left(\frac{\pi}{2}\cos\Theta\right)}{\sin\Theta}$$

$$I_\lambda = \int_0^\pi \left[\frac{\cos^2\left(\frac{\pi}{2}\cos\Theta\right)}{\sin\Theta}\right]^2 \sin\Theta\, d\Theta \approx 0.829532$$

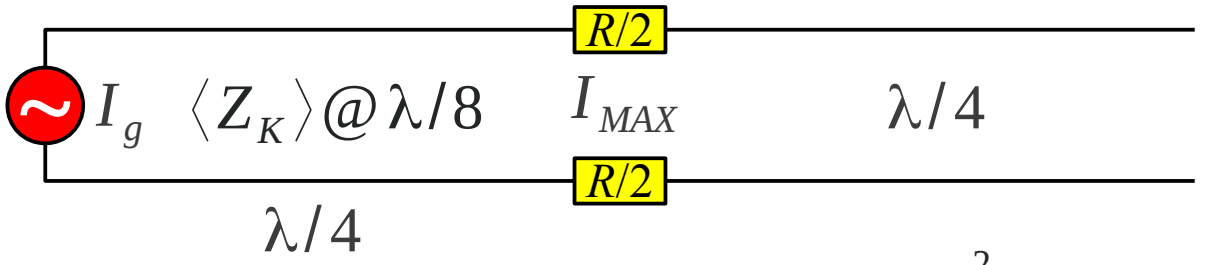
Tanka žica $w = 0.001\lambda$

$$D = \frac{2}{I_\lambda} \approx 2.41$$

$$D_{\mathrm{dBi}} = 10\log_{10}\frac{2}{I_\lambda} \approx 3.82\,\mathrm{dBi}$$

$$\Theta_A = \pi - \Theta_B \approx \frac{w}{\lambda/8}$$

$$P = \frac{Z_0}{\pi}\left|I_{MAX}\right|^2 I_\lambda$$

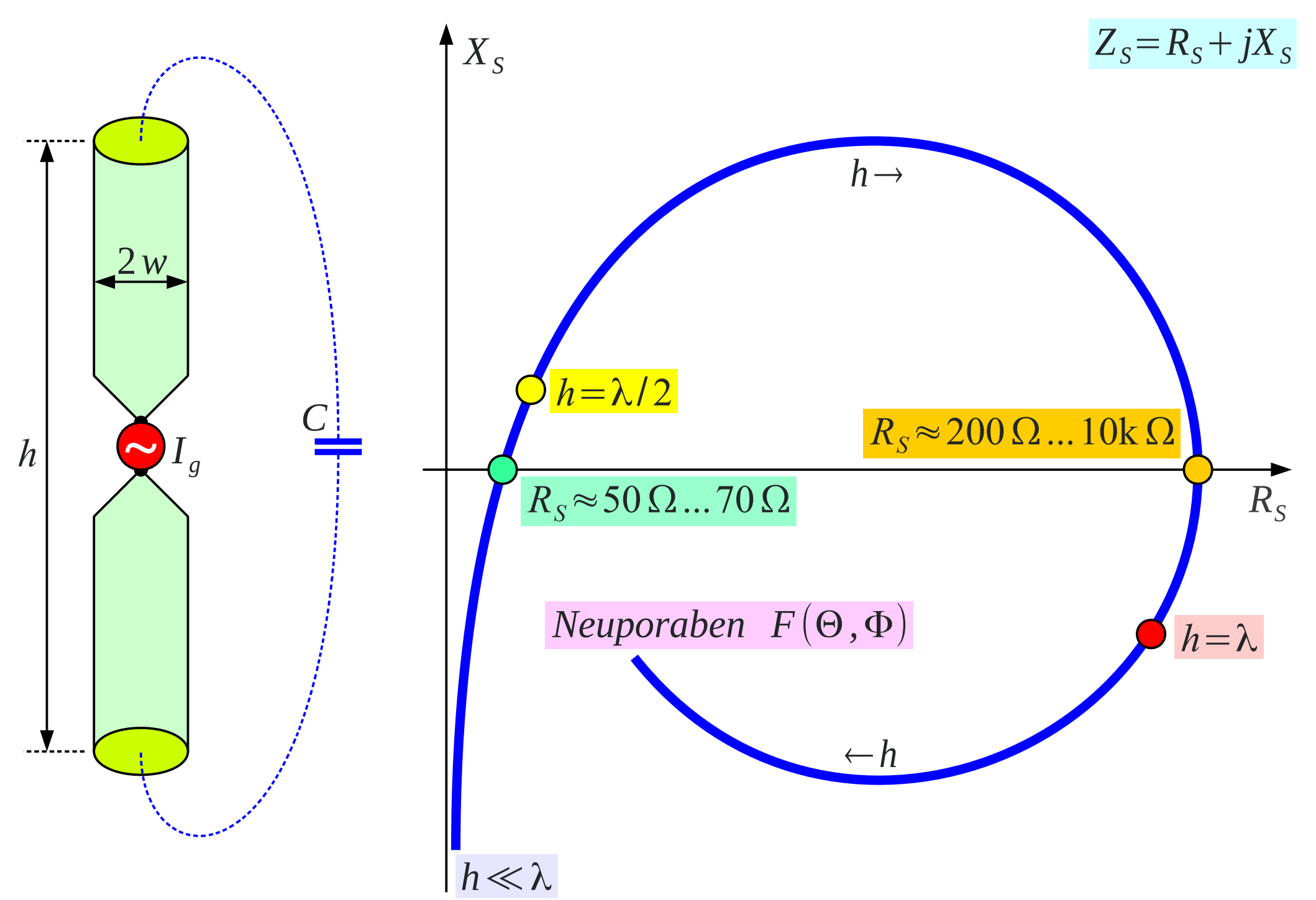


$$R = \frac{2P}{\left|I_{MAX}\right|^2} = \frac{2Z_0}{\pi} I_\lambda \approx 199\,\Omega$$

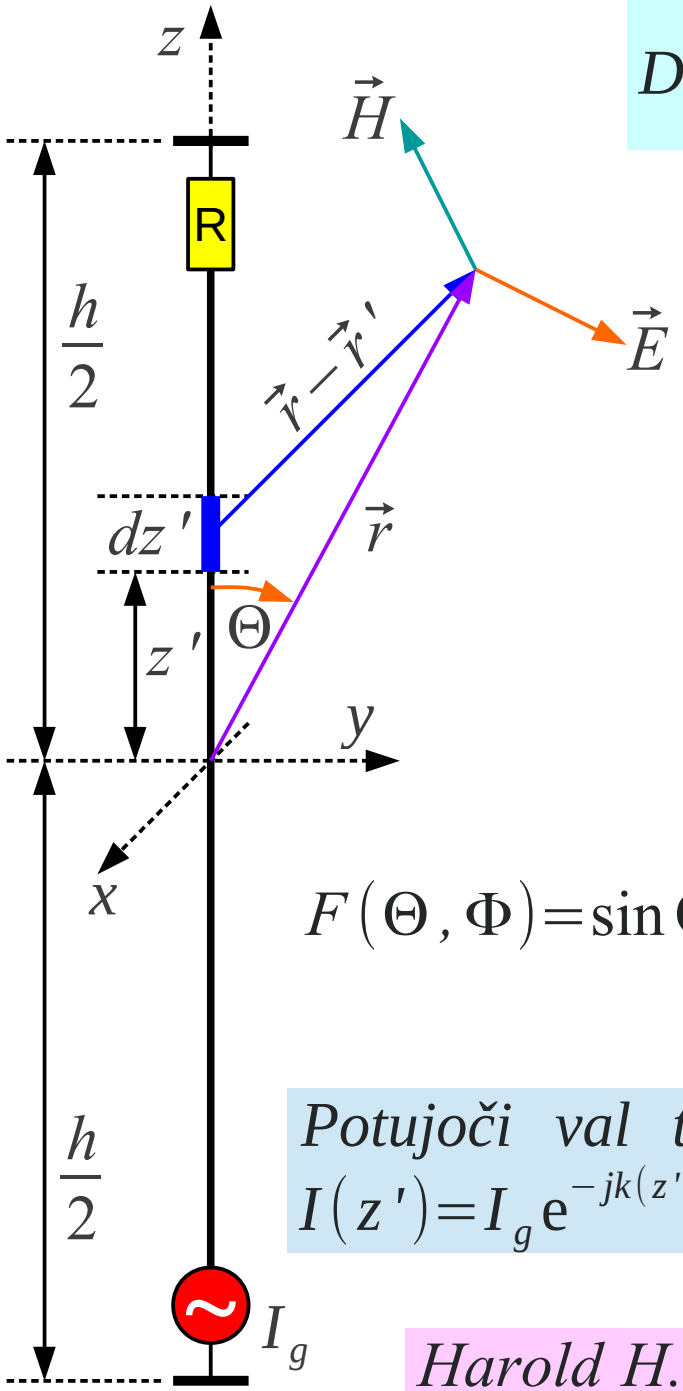
$$Z_K \approx 120\,\Omega \ln\frac{\lambda}{4w} \approx 663\,\Omega$$

$$R_S = \frac{Z_K^2}{R} \approx 2.2\,\mathrm{k}\Omega$$

Enovalovni dipol



Impedanca debelega dipola



$$\textit{Daljnje polje}\quad d\vec{E}\approx\vec{1}_\Theta\frac{jkZ_0}{4\pi}I(z')dz'\frac{e^{-jkr}}{r}e^{jkz'\cos\Theta}\sin\Theta$$

$$\vec{E}\approx\vec{1}_\Theta\frac{jZ_0}{2\lambda}I_g e^{-j\frac{kh}{2}}\frac{e^{-jkr}}{r}\sin\Theta\int_{-h/2}^{h/2}e^{jkz'(\cos\Theta-1)}dz'$$

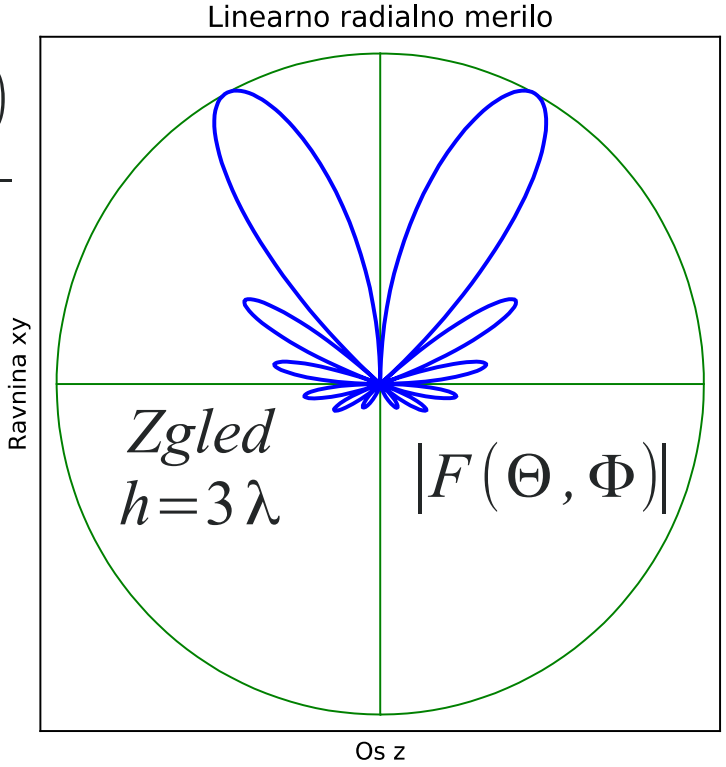
$$\vec{E}=\vec{1}_\Theta\frac{jZ_0}{2\lambda}I_g h e^{-j\frac{kh}{2}}\frac{e^{-jkr}}{r}\sin\Theta\frac{\sin\frac{kh}{2}(\cos\Theta-1)}{\frac{kh}{2}(\cos\Theta-1)}$$

$$F(\Theta,\Phi)=\sin\Theta\frac{\sin\frac{kh}{2}(\cos\Theta-1)}{\frac{kh}{2}(\cos\Theta-1)}$$

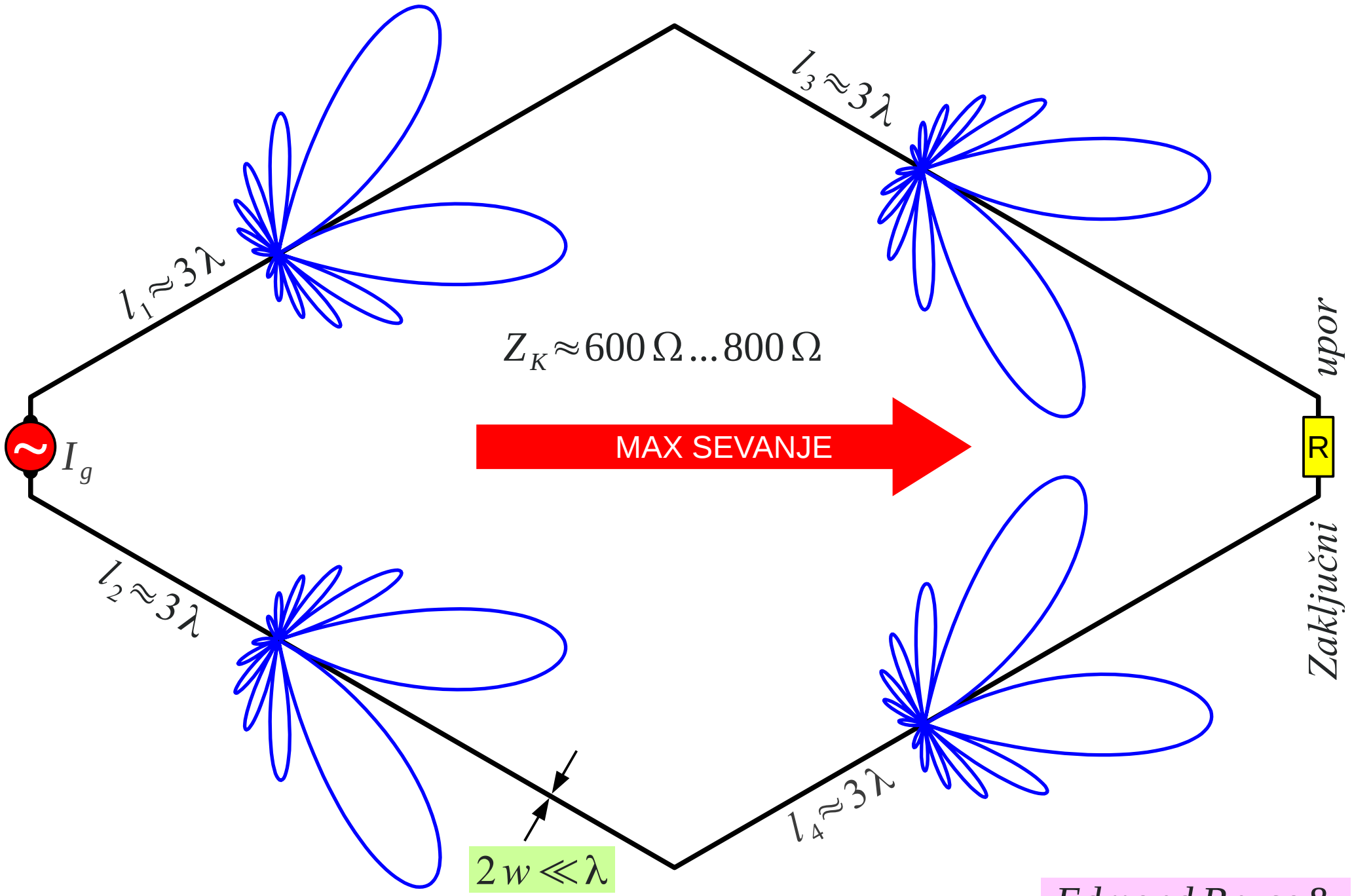
Potujoči val toka

$$I(z')=I_g e^{-jk(z'+h/2)}$$

Harold H. Beverage 1921



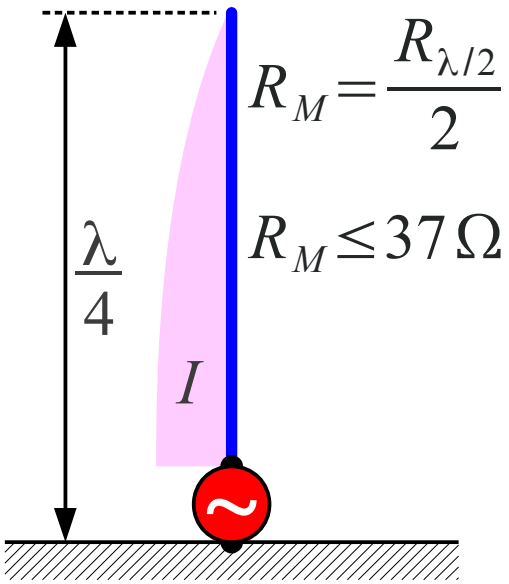
Sevanje potujočega vala na žici



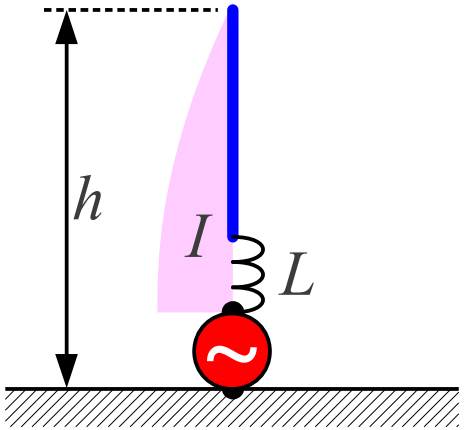
Romb antena

Edmond Bruce & Harald Friis 1931

$\lambda/4$ *monopol nad prevodno ravnino*

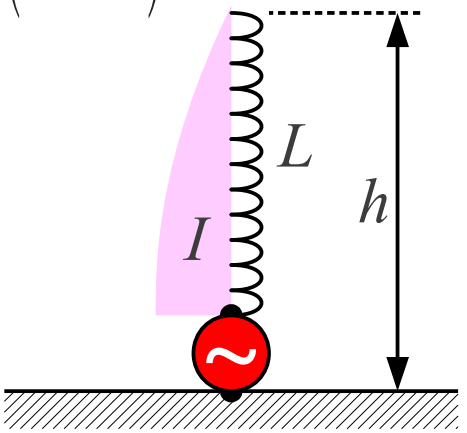


Koncentrirana tuljava



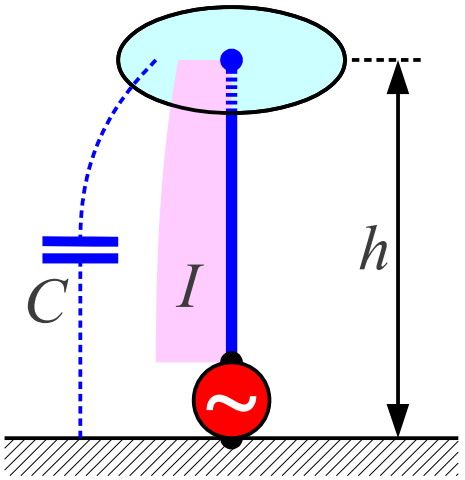
Porazdeljena tuljava

$$R_L \approx \frac{R_{\lambda/2}}{2}\left(\frac{h}{\lambda/4}\right)^2$$



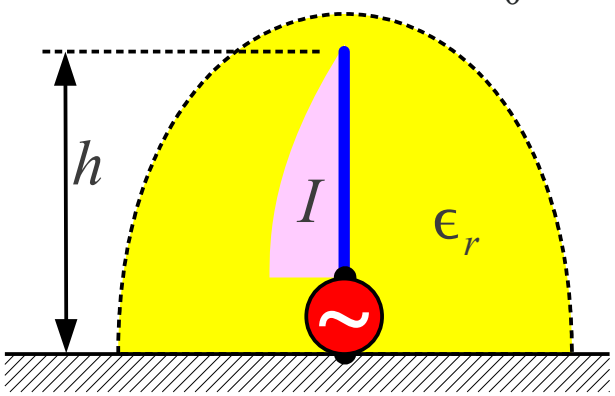
Kapacitivni klobuk

$$R_C \rightarrow 2\,R_L$$



Monopol v dielektriku

$$\lambda = \lambda_0 / \sqrt{\epsilon_r}$$



Skrajšane antene

Kapacitivni klobuk s transformacijo impedance