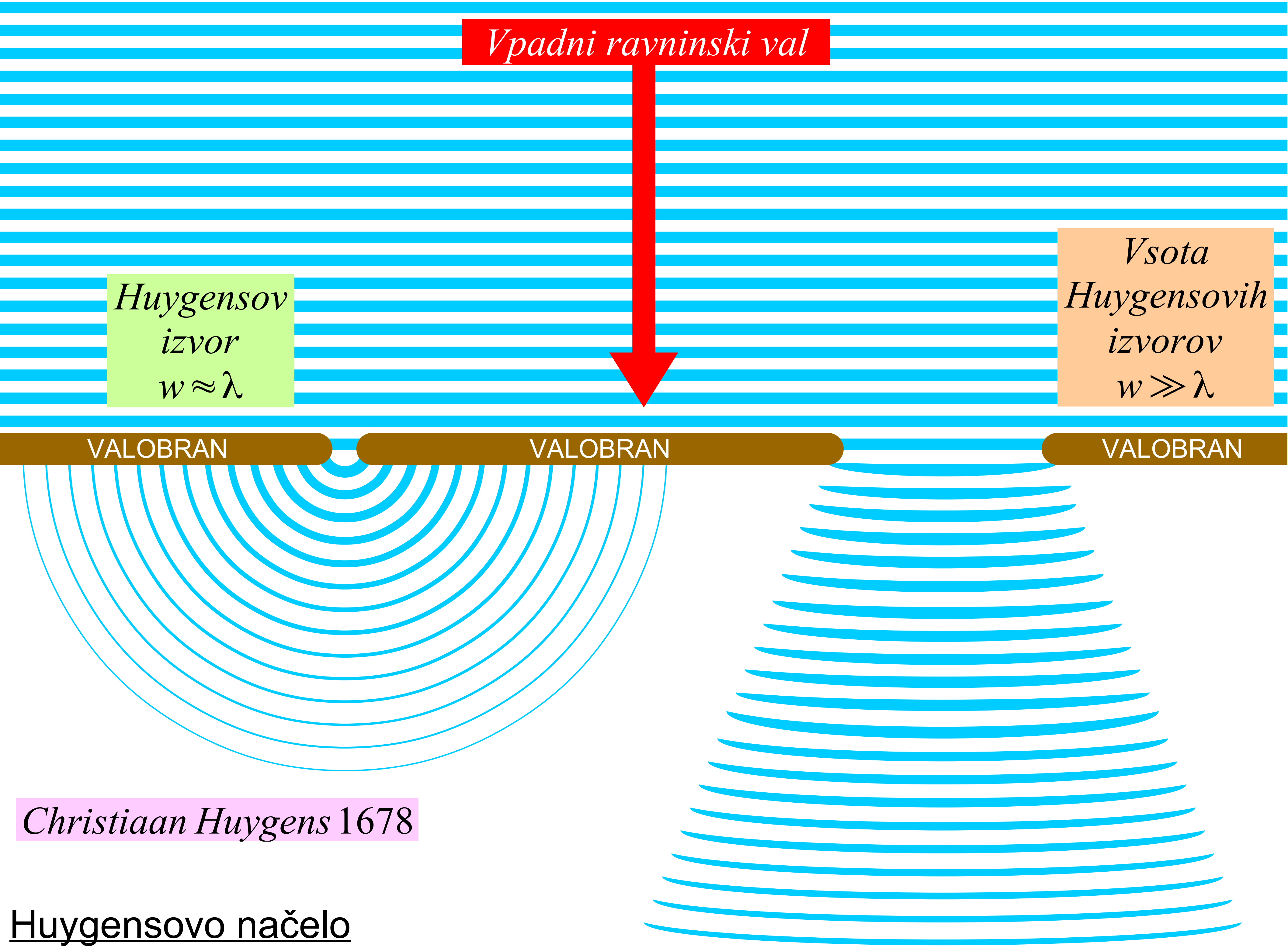
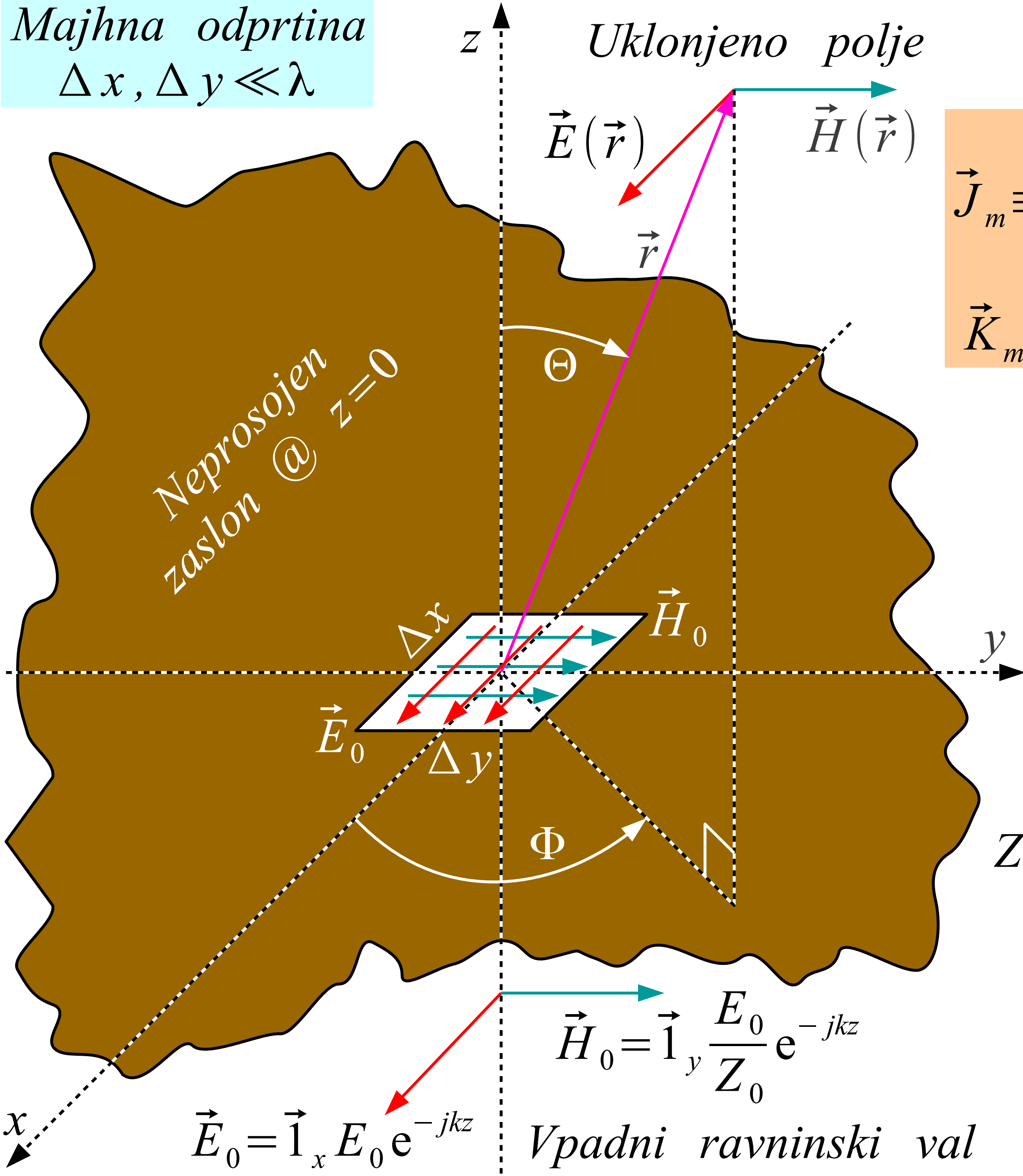
Huygens

Huygensovo načelo



Odprtina v zaslonu



Dodatne veličine

$\vec{J}_m \equiv$ *gostota magnetnega toka*

$\rho_m \equiv$ *gostota magnetin*

$\vec{K}_m \equiv$ *magnetni ploskovni tok*

Razširjene Maxwellove enačbe

$$\mathrm{rot}\,\vec{H}=\vec{J}+j\omega\epsilon\vec{E}$$

$$\mathrm{rot}\,\vec{E}=-\vec{J}_m-j\omega\mu\vec{H}$$

$$\mathrm{div}\,\epsilon\vec{E}=\rho$$

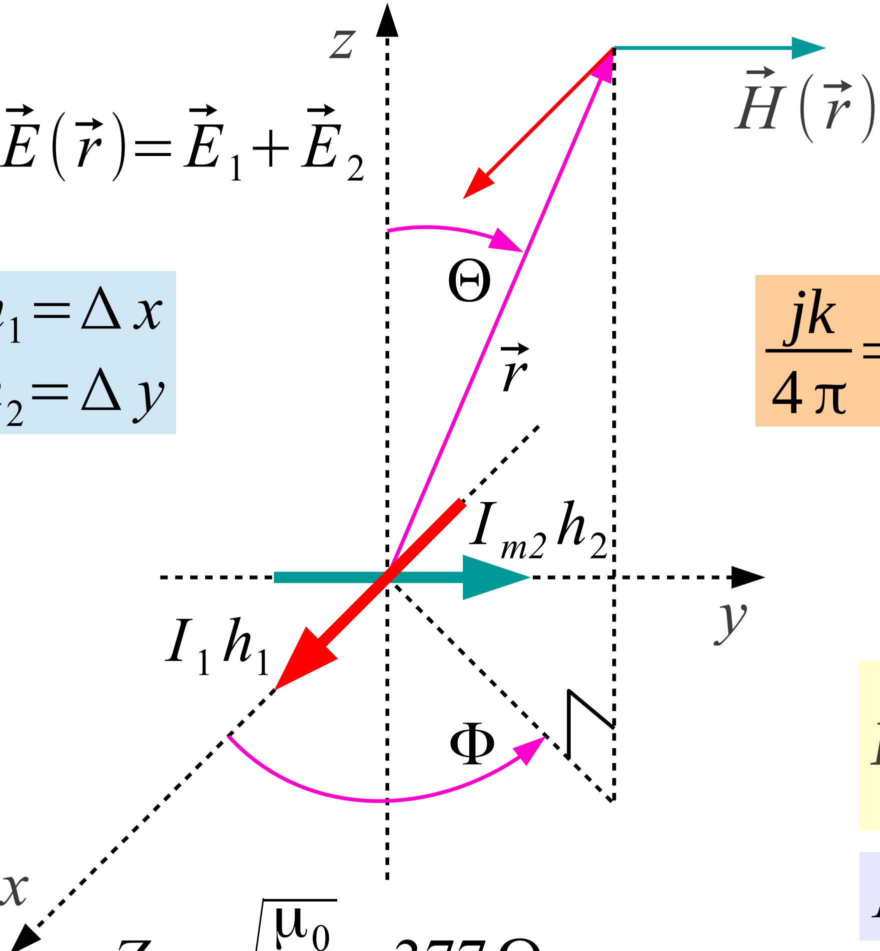
$$\mathrm{div}\,\mu\vec{H}=\rho_m$$

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

Nadomestni viri

$$\vec{K}=\vec{1}_z\times\vec{H}_0=-\vec{1}_x\frac{E_0}{Z_0}$$

$$\vec{K}_m=-\vec{1}_z\times\vec{E}_0=-\vec{1}_y E_0$$



$$\vec{E}(\vec{r}) = \vec{E}_1 + \vec{E}_2$$

$$h_1 = \Delta x$$
$$h_2 = \Delta y$$

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

Majhna odprtina
$\Delta x, \Delta y \ll \lambda$

$$\vec{E}_1 \approx \vec{1}_{\Theta x} \frac{jkZ_0}{4\pi} I_1 h_1 \frac{e^{-jkr}}{r} \sin\Theta_x$$

$$I_1 h_1 = \vec{1}_x \cdot \vec{K}\, \Delta x \Delta y = -\frac{E_0}{Z_0} \Delta x \Delta y$$

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

$$\vec{E}_1 \approx -\vec{1}_{\Theta x} \frac{j}{2\lambda} E_0 \Delta x \Delta y \frac{e^{-jkr}}{r} \sin\Theta_x$$

$$\vec{1}_{\Theta x} \sin\Theta_x = -\vec{1}_\Theta \cos\Theta \cos\Phi + \vec{1}_\Phi \sin\Phi$$

Dualnost $\quad \vec{H}_2 \approx \vec{1}_{\Theta y} \frac{jk}{4\pi Z_0} I_{m2} h_2 \frac{e^{-jkr}}{r} \sin\Theta_y$

$$I_{m2} h_2 = \vec{1}_y \cdot \vec{K}_m \Delta x \Delta y = -E_0 \Delta x \Delta y$$

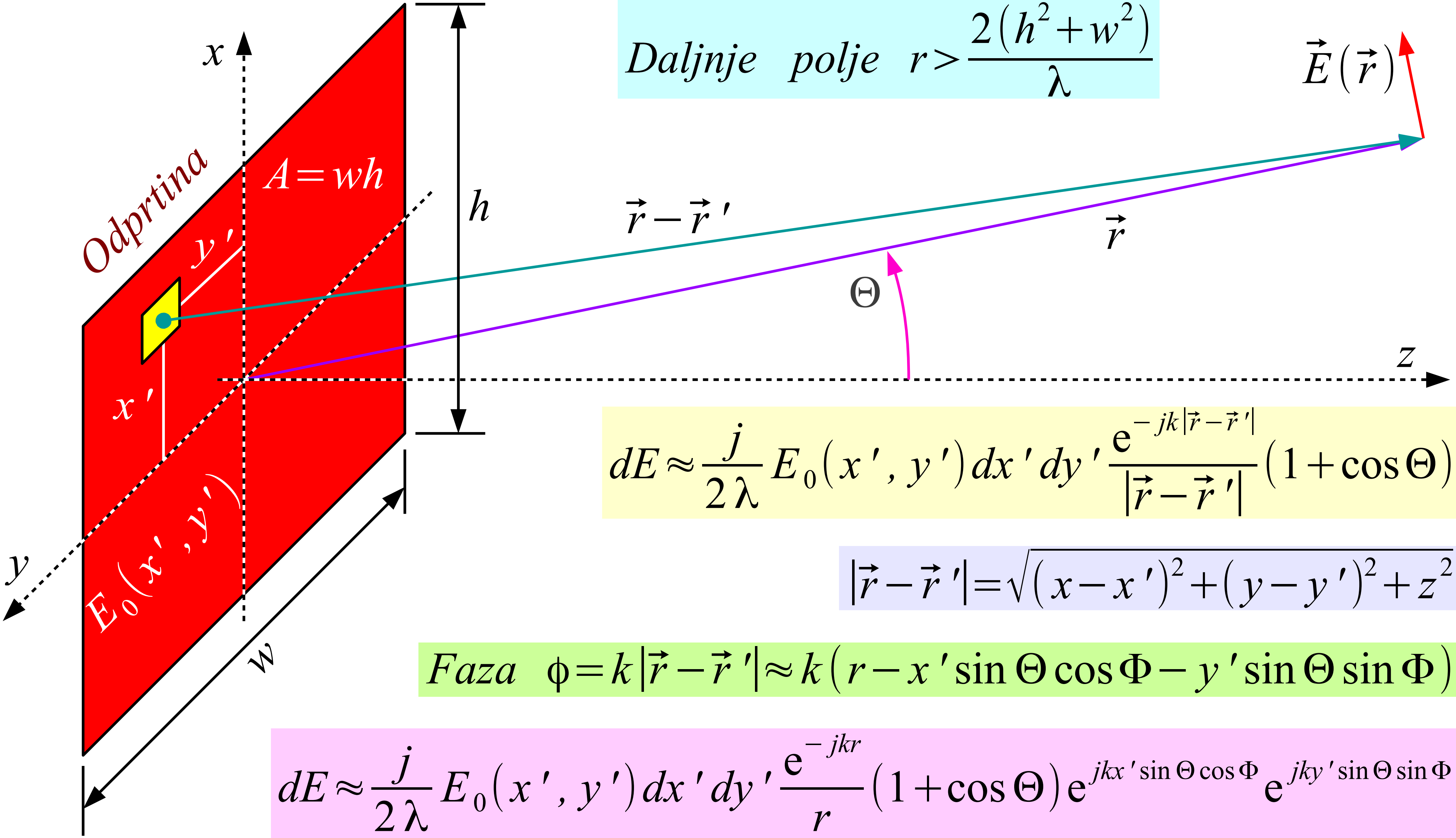
$$\vec{E}_2 = Z_0 \vec{H}_2 \times \vec{1}_r \approx \vec{1}_{\Phi y} \frac{j}{2\lambda} E_0 \Delta x \Delta y \frac{e^{-jkr}}{r} \sin\Theta_y$$

$$\vec{1}_{\Phi y} \sin\Theta_y = \vec{1}_\Theta \cos\Phi - \vec{1}_\Phi \cos\Theta \sin\Phi$$

$$\vec{E} = \vec{E}_1 + \vec{E}_2 \approx \left[\vec{1}_\Theta \cos\Phi - \vec{1}_\Phi \sin\Phi\right] \frac{j}{2\lambda} E_0 \Delta x \Delta y \frac{e^{-jkr}}{r} (1 + \cos\Theta)$$

<u>Sevanje nadomestnih virov</u>

Daljnje polje $r > \dfrac{2(h^2+w^2)}{\lambda}$



$$dE \approx \frac{j}{2\lambda} E_0(x',y')\,dx'\,dy'\,\frac{e^{-jk|\vec{r}-\vec{r}\,'|}}{|\vec{r}-\vec{r}\,'|}(1+\cos\Theta)$$

$$|\vec{r}-\vec{r}\,'| = \sqrt{(x-x')^2+(y-y')^2+z^2}$$

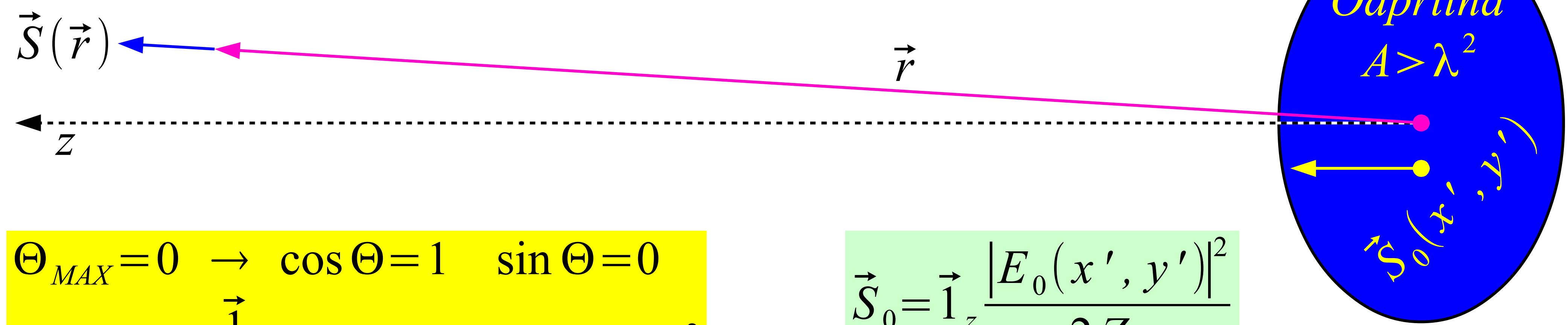
Faza $\phi = k|\vec{r}-\vec{r}\,'| \approx k(r - x'\sin\Theta\cos\Phi - y'\sin\Theta\sin\Phi)$

$$dE \approx \frac{j}{2\lambda} E_0(x',y')\,dx'\,dy'\,\frac{e^{-jkr}}{r}(1+\cos\Theta)\,e^{jkx'\sin\Theta\cos\Phi}\,e^{jky'\sin\Theta\sin\Phi}$$

$$E = \iint_A dE \approx \frac{j}{2\lambda}\frac{e^{-jkr}}{r}(1+\cos\Theta)\int_{-h/2}^{h/2}\int_{-w/2}^{w/2} E_0(x',y')\,e^{jkx'\sin\Theta\cos\Phi}\,e^{jky'\sin\Theta\sin\Phi}\,dx'\,dy'$$

Vsota Huygensovih izvorov

$$\vec{S}=\vec{1}_r\frac{|E|^2}{2Z_0}=\vec{1}_r\frac{(1+\cos\Theta)^2}{8Z_0\lambda^2r^2}\left|\iint_A E_0(x',y')\,e^{jkx'\sin\Theta\cos\Phi}\,e^{jky'\sin\Theta\sin\Phi}\,dA\right|^2$$



$$\Theta_{MAX}=0 \quad\rightarrow\quad \cos\Theta=1 \qquad \sin\Theta=0$$

$$\vec{S}_{MAX}=\frac{\vec{1}_r}{2Z_0\lambda^2r^2}\left|\iint_A E_0(x',y')\,dA\right|^2$$

$$\vec{S}_0=\vec{1}_z\frac{|E_0(x',y')|^2}{2Z_0}$$

$$P=\iint_A \vec{S}_0\cdot\vec{1}_z\,dA=\iint_A\frac{|E_0(x',y')|^2}{2Z_0}\,dA$$

$$D=\frac{|\vec{S}_{MAX}|}{P/(4\pi r^2)}=\frac{4\pi\left|\iint_A E_0(x',y')\,dA\right|^2}{\lambda^2\iint_A|E_0(x',y')|^2\,dA}$$

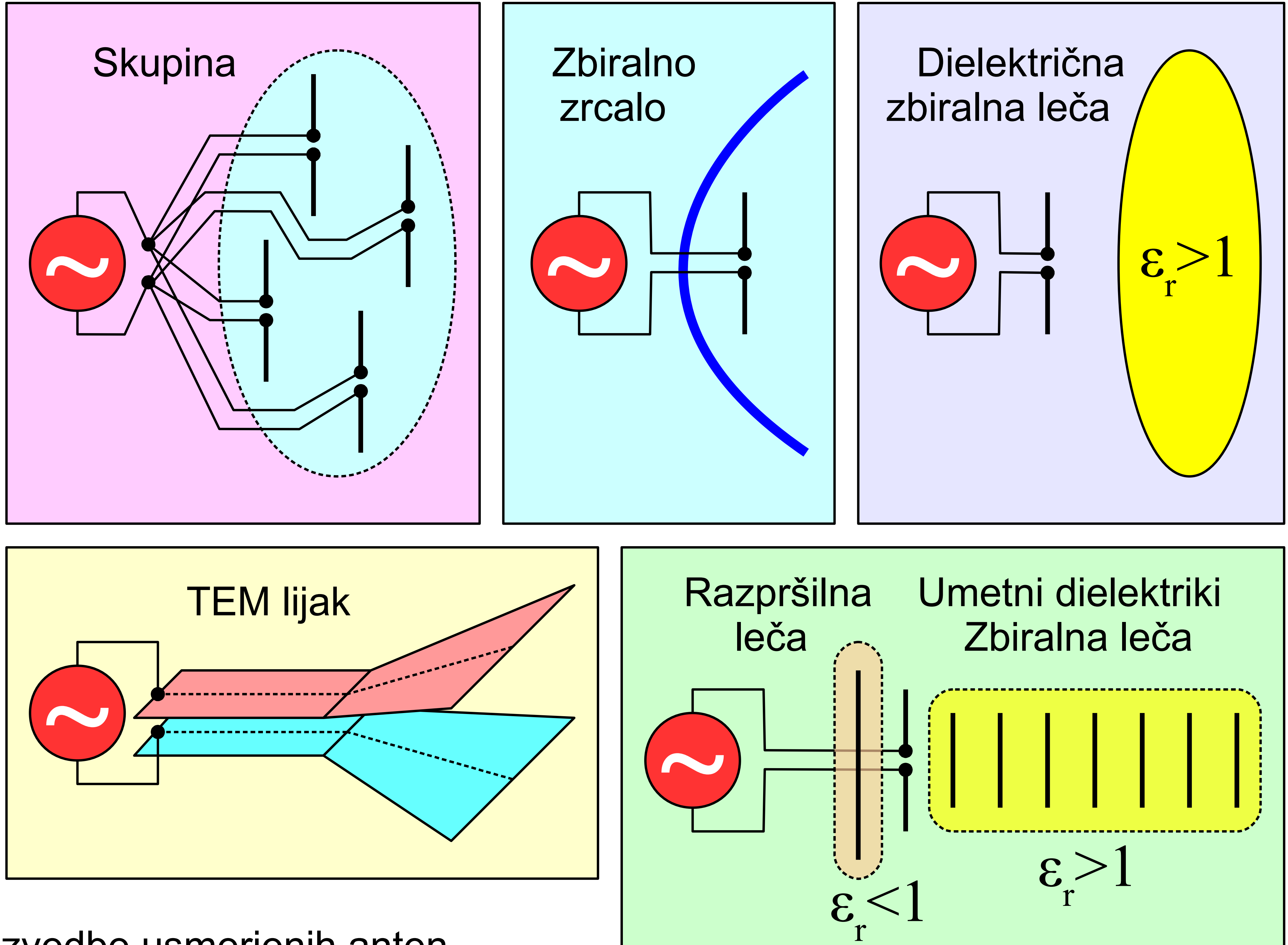
$$A_{eff}=\frac{\left|\iint_A E_0(x',y')\,dA\right|^2}{\iint_A|E_0(x',y')|^2\,dA}$$

Zgled $\quad E_0(x',y')=konst. \quad\rightarrow\quad D=\frac{4\pi}{\lambda^2}A$

$$D=\frac{4\pi}{\lambda^2}A_{eff}=\frac{4\pi}{\lambda^2}\eta_0A$$

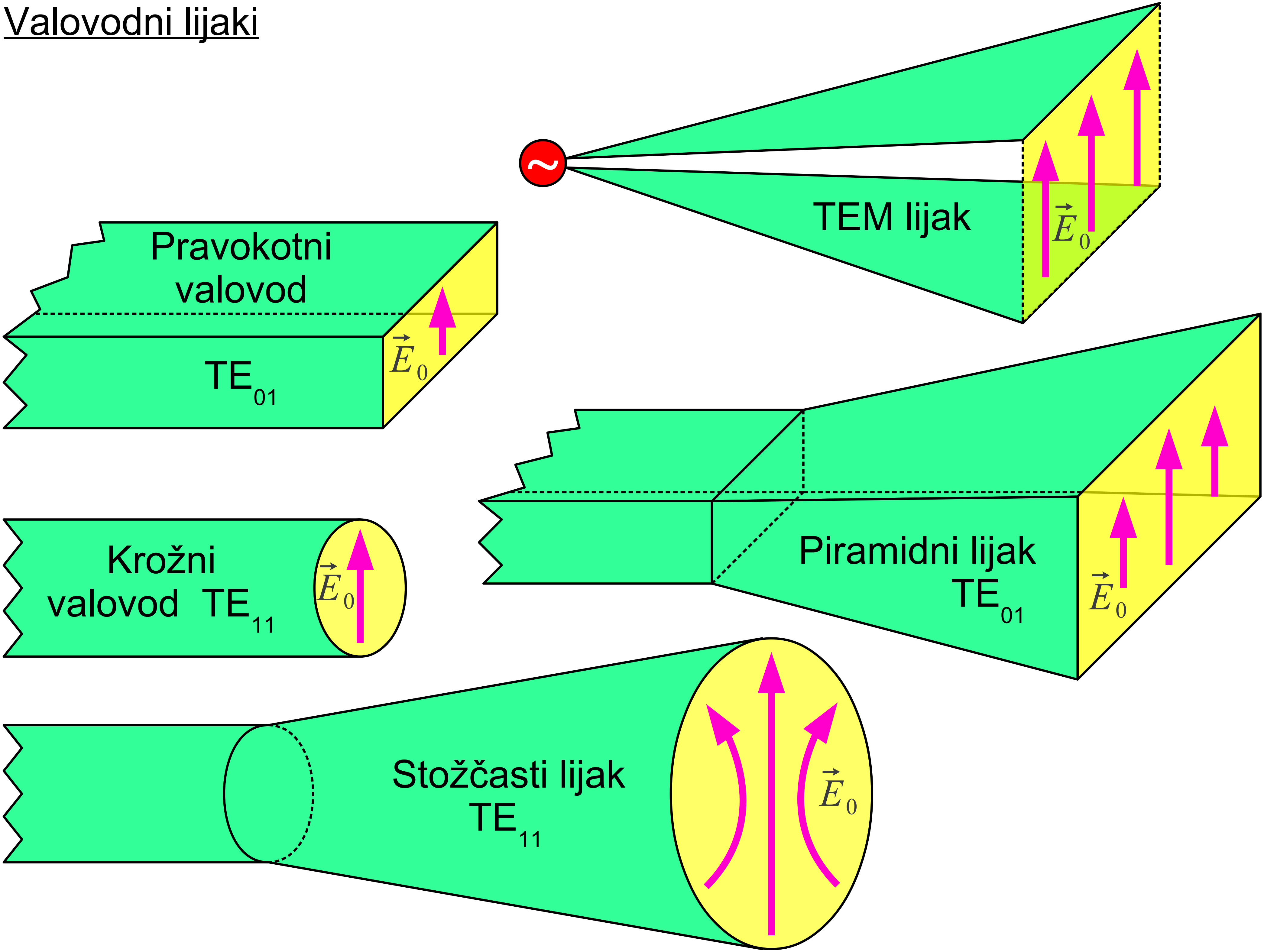
$$\eta_0=\frac{\left|\iint_A E_0(x',y')\,dA\right|^2}{A\iint_A|E_0(x',y')|^2\,dA}$$

Smernost odprtine v smeri z

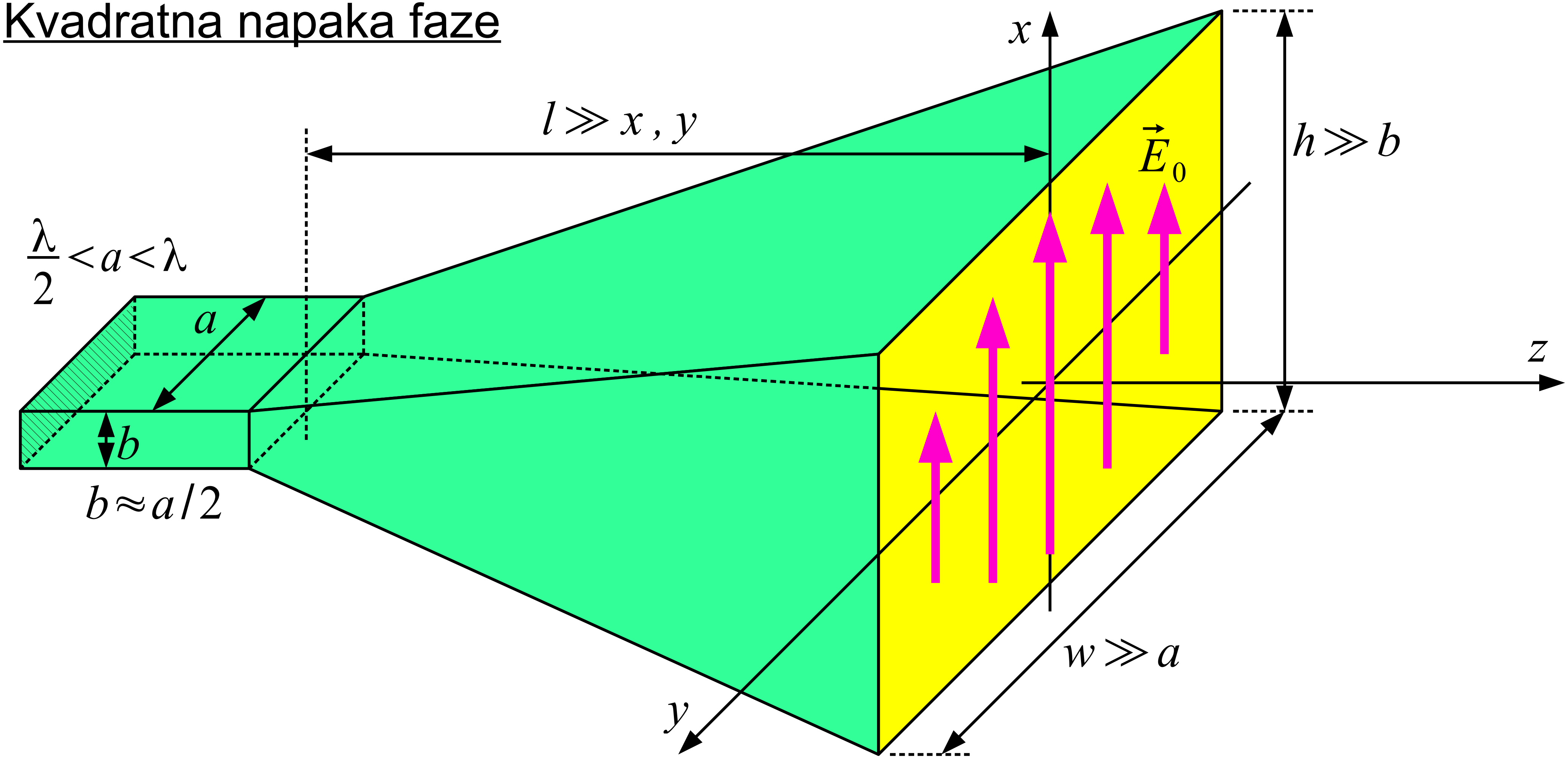


Izvedbe usmerjenih anten

Valovodni lijaki



Kvadratna napaka faze



$$\Delta\phi = k\left[\sqrt{l^2+x^2+y^2}-l\right] \approx \frac{k\left(x^2+y^2\right)}{2l} = \frac{\pi\left(x^2+y^2\right)}{\lambda l}$$

$$\vec{E}_0(x, y, z=0) \approx \vec{1}_x C \cos\left(\frac{\pi}{w} y\right) e^{-j\Delta\phi(x,y)}$$

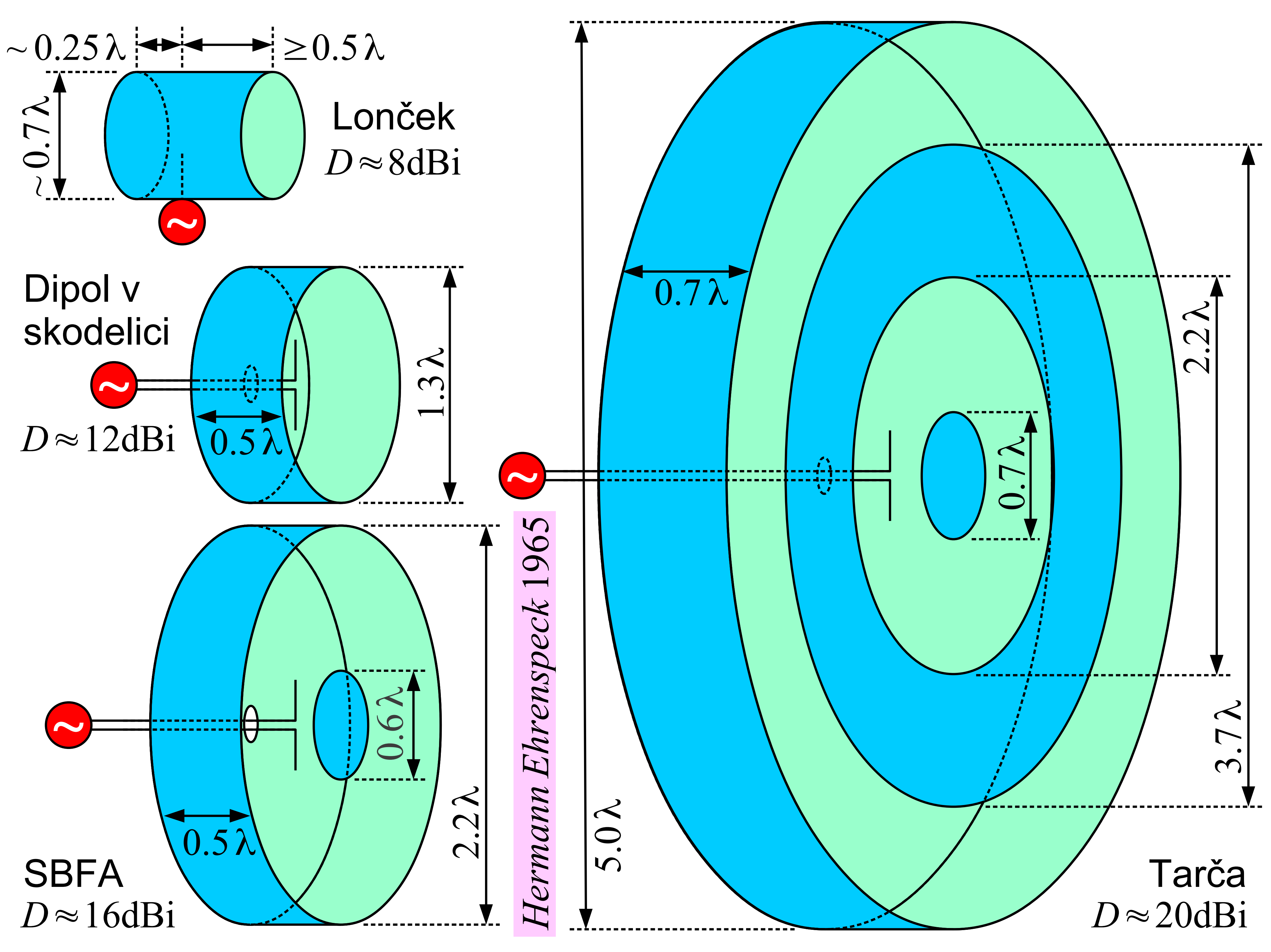
Optimalni lijak

$$\Delta\phi_E \le \pi/2 \rightarrow h \approx \sqrt{2\lambda l}$$

$$\Delta\phi_H \le 3\pi/4 \rightarrow w \approx \sqrt{3\lambda l}$$

$$\eta_0 \approx 50\%$$

Zelo dolgi lijak $\Delta\phi \le \pi/8 \rightarrow l \approx 2\left(w^2+h^2\right)/\lambda \rightarrow \eta_0 \approx 81\%$


~0.25 λ
≥0.5 λ
~0.7λ
Lonček
D ≈ 8dBi
Dipol v skodelici
1.3λ
0.5 λ
D ≈ 12dBi
SBFA
0.6λ
0.5λ
2.2λ
D ≈ 16dBi
Hermann Ehrenspeck 1965
0.7 λ
5.0λ
2.2λ
3.7λ
0.7λ
Tarča
D ≈ 20dBi