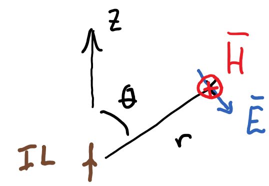
HERTZIN DIPOLI (kaukokenttä)



$$\bar{E}(\bar{r}) = j\underbrace{\omega\mu}_{k\eta} IL \frac{e^{-jkr}}{4\pi r} \sin\theta \, \bar{u}_\theta$$

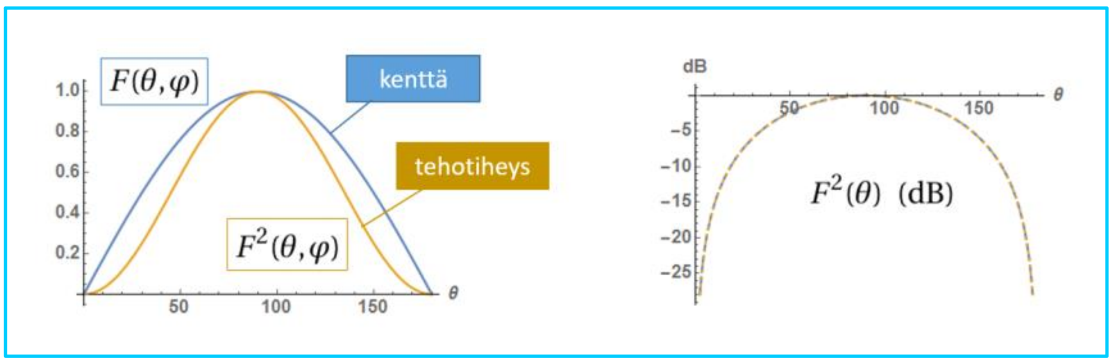
$$\bar{H}(\bar{r}) = jkIL \frac{e^{-jkr}}{4\pi r} \sin\theta \, \bar{u}_\varphi$$

$$\omega\mu = k\eta = \omega\sqrt{\mu\varepsilon}\sqrt{\frac{\mu}{\varepsilon}} = \omega\mu$$

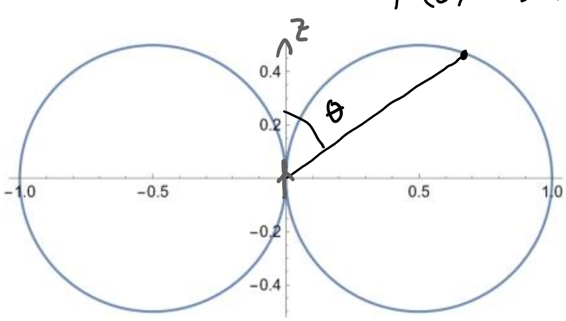
$$\eta\bar{H} = \bar{u}_r \times \bar{E}$$

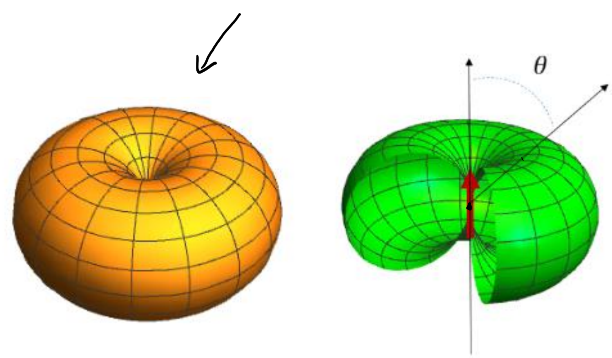
SUUNTAKUVIO $\quad F(\theta,\varphi) = \dfrac{|E(\theta,\varphi)|}{|E_{max}|}$

Hertz: $\quad F(\theta) = \sin\theta$



$$F(\theta) = \sin\theta$$





SUUNTAAVUUS D

$F(\theta,\varphi)$ ← kenttä

$F^2(\theta,\varphi)$ ← tehotiheys

$$d\Omega = \sin\theta \, d\theta \, d\varphi$$

$$\int d\Omega = \int_0^{2\pi} d\varphi \int_0^{\pi} \sin\theta \, d\theta$$

$$D = \frac{4\pi}{\quad}$$

$$D = \frac{4\pi}{\int F^2(\theta,\varphi)\, d\Omega}$$

$$\int d\Omega = \int_0 d\varphi \int_0 \sin\theta\, d\theta = 2\pi \cdot 2 = 4\pi$$

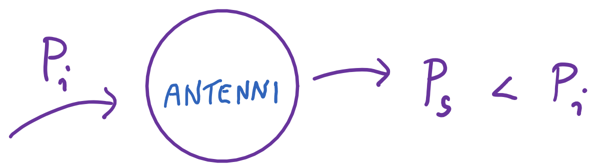
Hertzin dipolin suuntaavuus $F(\theta,\varphi) = \sin\theta$

$$\int \sin^2\theta\, d\Omega = \underbrace{\int_0^{2\pi} d\varphi}_{2\pi} \int_0^{\pi} \underbrace{\sin^2\theta}_{1-\cos^2\theta} \sin\theta\, d\theta = 2\pi\left(\underbrace{\int_0^{\pi}\sin\theta\, d\theta}_{2} - \underbrace{\int_0^{\pi}\sin\theta \cos^2\theta\, d\theta}_{2/3}\right) = \frac{8\pi}{3}$$

$$D = \frac{4\pi}{8\pi/3} = 3/2 = 1{,}5$$

$$\boxed{10 \lg 1{,}5 = 1{,}76\ \text{dB}}$$

VAHVISTUS G

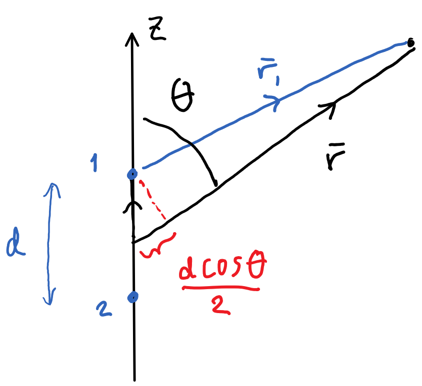


$$G = \eta D$$

hyötysuhde η : $\quad P_s = \eta P_i$

ANTENNIRYHMÄT

KAKSI SÄTEILIJÄÄ



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

$$\bar{E}_0 = j\omega\mu I L \frac{e^{-jkr}}{4\pi r} \sin\theta\, \bar{u}_\theta \qquad kr = 2\pi r/\lambda$$

$$r >> d$$

$$\bar{r}_{1,2} = \bar{r} \mp \frac{d}{2}\bar{u}_z$$

$$r_{1,2} = \sqrt{\left(\bar{r} \mp \frac{d}{2}\bar{u}_z\right)\cdot\left(\bar{r} \mp \frac{d}{2}\bar{u}_z\right)} = \sqrt{r^2 \mp d r \cos\theta + d^2/4}$$

$$= r\sqrt{1 \mp \frac{d\cos\theta}{r} + \cancel{\left(\frac{d}{2r}\right)^2}} \simeq r\left(1 \mp \frac{d\cos\theta}{2r}\right)$$

$$= r \mp \frac{d\cos\theta}{2}$$

$$e^{-jkr_1} = e^{-jk\left(r - \frac{d\cos\theta}{2}\right)} = e^{-jkr} \cdot e^{j\frac{kd\cos\theta}{2}}$$

$$e^{-jkr_2} = e^{-jk\left(r + \frac{d\cos\theta}{2}\right)} = e^{-jkr} \cdot e^{-j\frac{kd\cos\theta}{2}}$$

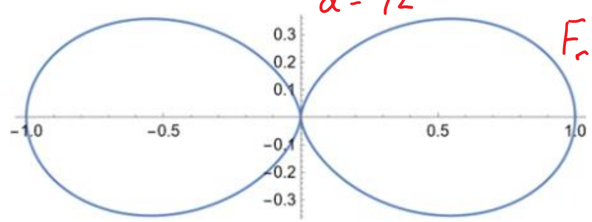
$$\bar{E}(\bar{r}) = \bar{E}_1(\bar{r}) + \bar{E}_2(\bar{r}) = \bar{E}_0(\bar{r})\left(e^{j\frac{kd\cos\theta}{2}} + e^{-j\frac{kd\cos\theta}{2}}\right)$$

$$= \bar{E}_0(\bar{r}) \cdot \underbrace{2\cos\left(\frac{kd\cos\theta}{2}\right)}_{\text{RYHMÄKUVIO}}$$

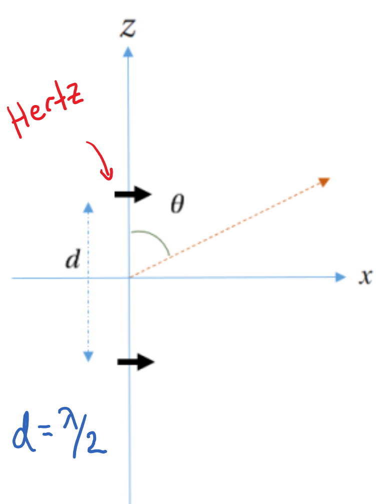
$$d = \lambda/2 \Rightarrow \frac{kd}{2} = \frac{\pi}{2}$$

$$\Rightarrow \cos\left(\frac{\pi}{2}\cos\theta\right)$$

$d = \lambda/2$ F_r



ESIMERKKI



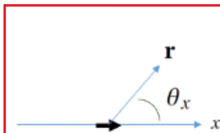
Ryhmäkuvio:

$$F_r(\theta) = \cos\left(\frac{\pi}{2}\cos\theta\right)$$

Elementin säteilykuvio:

$$F_e(\theta,\varphi) = |\sin\theta_x|$$

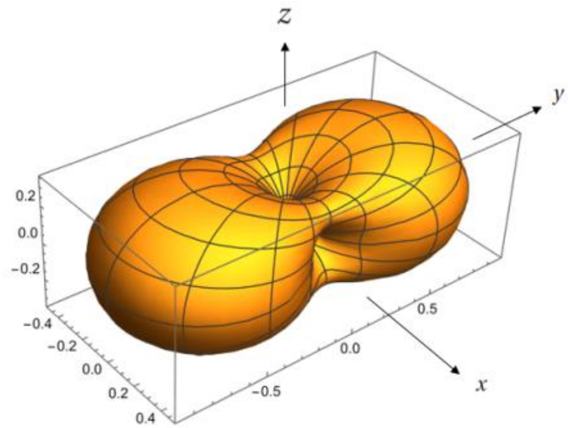
$$F_e(\theta,\varphi) = \sqrt{1-(\sin\theta\cos\varphi)^2}$$



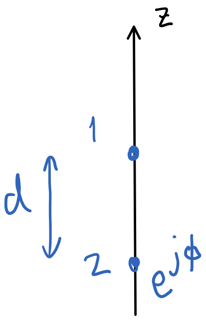
$$\cos\theta_x = \mathbf{u}_x \cdot \mathbf{u}_r = \sin\theta\cos\varphi$$

Koko säteilykuvio:

$$F(\theta,\varphi) = \sqrt{1-(\sin\theta\cos\varphi)^2}\,\cos\left(\frac{\pi\cos\theta}{2}\right)$$



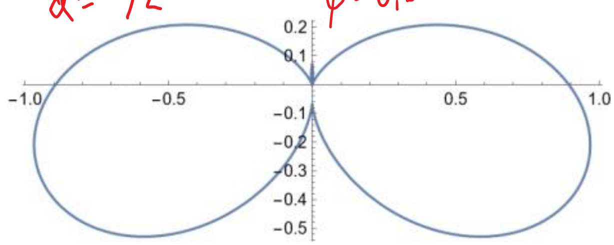
VAIHEISTETTU SYÖTTÖ



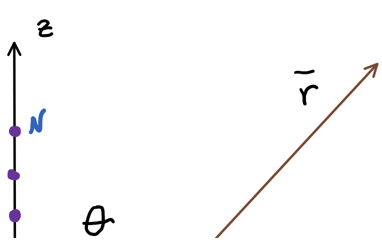
$$e^{j\frac{kd\cos\theta}{2}} + e^{j\phi}\cdot e^{-j\frac{kd\cos\theta}{2}}$$

$$= e^{j\phi/2}\Big(\underbrace{\underbrace{e^{-j\phi/2}\cdot e^{j\frac{kd\cos\theta}{2}} + e^{+j\phi/2}\cdot e^{-j\frac{kd\cos\theta}{2}}}_{e^{j\frac{kd\cos\theta-\phi}{2}} + e^{-j\frac{kd\cos\theta-\phi}{2}}}}_{2\cos\left(\frac{kd\cos\theta-\phi}{2}\right)}\Big)$$

$d = \lambda/2$ $\phi = 0{,}3$

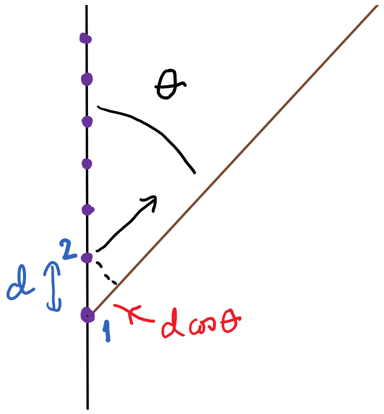


n-elementtinen ryhmä



$\bar{E}(\bar{r}) = ?$

$$1 + e^{jkd\cos\theta} + e^{2jkd\cos\theta} + \dots e^{j(N-1)kd\cos\theta}$$



$$1 + e^{jkd\cos\theta} + e^{2jkd\cos\theta} + \cdots e^{j(N-1)kd\cos\theta}$$

Geometrinen sarja

$$S = 1 + a + a^2 + \cdots a^{N-1}$$
$$aS = a + a^2 + \cdots + a^N$$
$$aS - S = a^N - 1 \quad \Rightarrow \quad S = \frac{a^N - 1}{a - 1}$$

Ryhmäkuvio

$$= \frac{e^{jNkd\cos\theta} - 1}{e^{jkd\cos\theta} - 1} = \frac{e^{jN\frac{kd}{2}\cos\theta}}{e^{j\frac{kd}{2}\cos\theta}} \cdot \frac{e^{j\frac{Nkd\cos\theta}{2}} - e^{-j\frac{kd\cos\theta}{2}}}{\underbrace{e^{j\frac{kd\cos\theta}{2}} - e^{-j\frac{kd\cos\theta}{2}}}_{2j\sin\frac{kd\cos\theta}{2}}}$$

$$|\text{Ryhmäkuvio}| = \frac{\sin\frac{Nkd\cos\theta}{2}}{\sin\frac{kd\cos\theta}{2}}$$

$\sin\alpha \simeq \alpha$

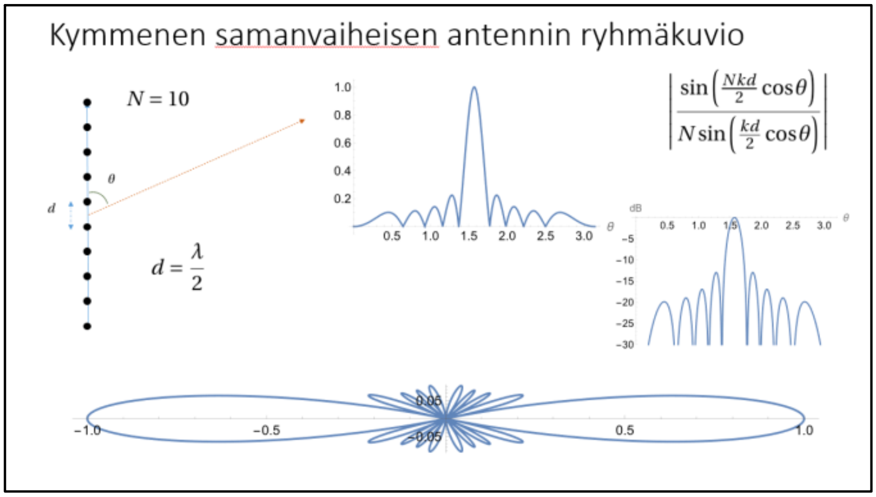
$\alpha << 1$

$\theta = \pi/2 \Rightarrow \cos\theta = 0$

$\downarrow$

$$\theta \simeq 90^\circ \Rightarrow \frac{\frac{Nkd\cos\theta}{2}}{\frac{kd\cos\theta}{2}} = N$$

$\Rightarrow$ Normalisoitu ryhmäkuvio: $\left|\frac{\sin\left(\frac{Nkd\cos\theta}{2}\right)}{N\sin\left(\frac{kd\cos\theta}{2}\right)}\right|$



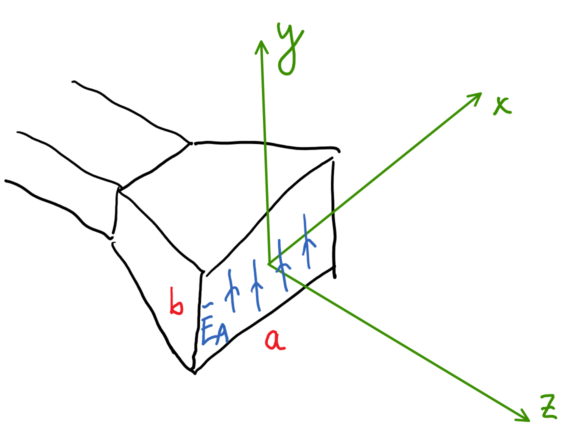
APERTUURIANTENNIT

pinnalla kentät $\bar{E}, \bar{H}$

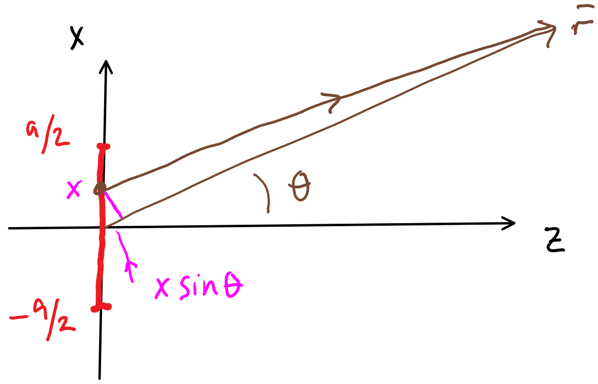
$\sim$ ekvivalenttiset lähteet $\bar{J}$

(säteilevät vapaaseen tilaan)

= HUYGENSIN PERIAATE



$$j\omega\mu I h \frac{e^{-jkr}}{4\pi r} \sin\theta \, \bar{u}_\theta$$



$$e^{-jkr}$$

$$\int_{-a/2}^{+a/2} E_A(x)\, e^{jkx\sin\theta}\, dx$$

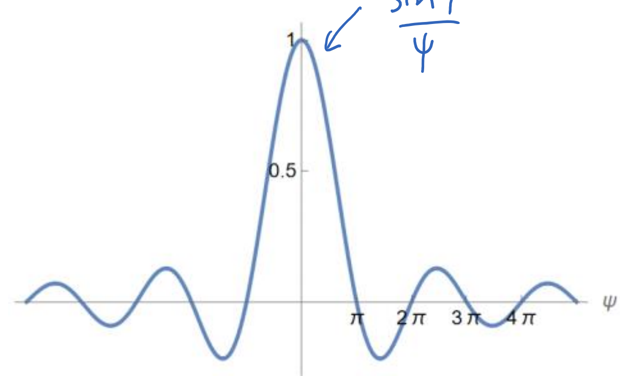
Vakiokenttä apertuurissa $E_A(x) = E_0$

$$\int_{-a/2}^{+a/2} e^{+jkx\sin\theta}\, dx = \Bigg/_{-a/2}^{+a/2} \frac{e^{jkx\sin\theta}}{jk\sin\theta} = \frac{e^{j\frac{ka\sin\theta}{2}} - e^{-j\frac{ka\sin\theta}{2}}}{jk\sin\theta}$$

$$= \frac{a}{2}\,\frac{2j\sin\frac{ka\sin\theta}{2}}{\frac{a}{2}jk\sin\theta} = a\,\frac{\sin\psi}{\psi} \qquad \left(\psi = \frac{ka\sin\theta}{2}\right)$$

sinc-funktio

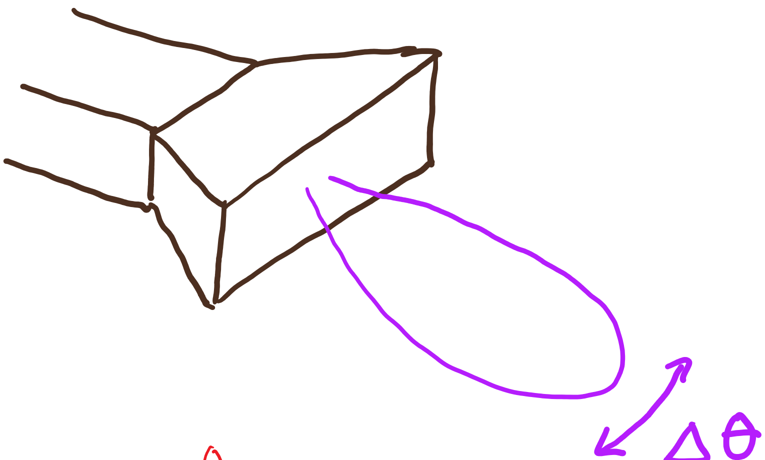
$\frac{\sin\psi}{\psi}$

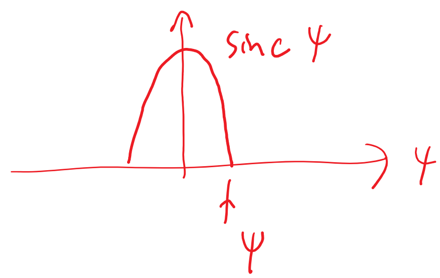


Aukkoantenni, tasainen syöttö

$$F(\theta) = \frac{\sin\psi}{\psi}$$

$$\psi = \frac{ka\sin\theta}{2}$$





$$\frac{ka\sin\overbrace{\theta}^{\theta}}{2} = \pi$$

$$\Rightarrow \quad \frac{\cancel{2}\cancel{\pi}}{\lambda}\frac{a}{\cancel{2}}\cdot\theta = \cancel{\pi}$$

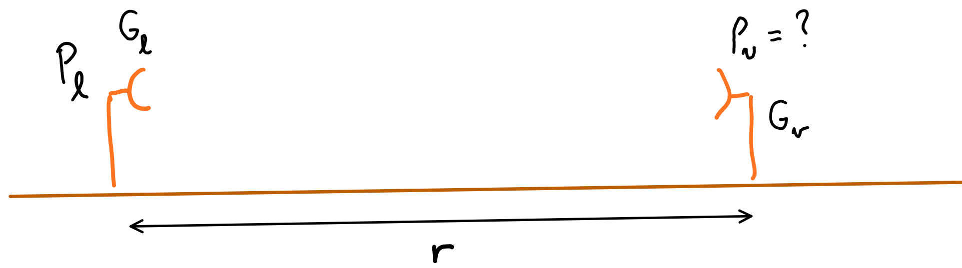
$$\Delta\theta \simeq \frac{\lambda}{a}$$

SIEPPAUSPINTA A_e

$$D = \frac{4\pi}{\Omega_p} = \frac{4\pi}{\frac{\lambda}{a}\cdot\frac{\lambda}{b}} = \frac{4\pi}{\lambda^2}\overbrace{ab}^{A}$$

$$G = \frac{4\pi}{\lambda^2}A_e$$

AALTOJEN ETENEMINEN



(λ)

$$S_v = \frac{G_\ell P_\ell}{4\pi r^2}$$

$$P_v = A_e S_v = \frac{\lambda^2}{4\pi} G_v \frac{G_\ell P_\ell}{4\pi r^2}$$

Vapaan tilan vaimennus $\left(\frac{\lambda}{4\pi r}\right)^2$

FRIISIN KAAVA

$$P_v = P_\ell G_\ell G_v \left(\frac{\lambda}{4\pi r}\right)^2$$