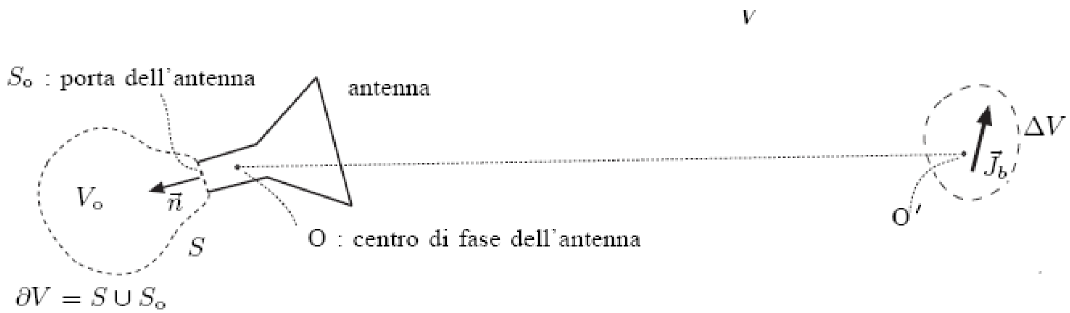
Reciprocità

$$\begin{aligned}\nabla \times \vec{H}_{\mathsf{a}} &= j\,\omega\,\epsilon\,\vec{E}_{\mathsf{a}} + \vec{J}_{\mathsf{a}} \\ \nabla \times \vec{E}_{\mathsf{a}} &= -j\,\omega\,\mu\,\vec{H}_{\mathsf{a}} - \vec{M}_{\mathsf{a}}\end{aligned}$$

$$\begin{aligned}\nabla \times \vec{H}_{\mathsf{b}} &= j\,\omega\,\epsilon\,\vec{E}_{\mathsf{b}} + \vec{J}_{\mathsf{b}} \\ \nabla \times \vec{E}_{\mathsf{b}} &= -j\,\omega\,\mu\,\vec{H}_{\mathsf{b}} - \vec{M}_{\mathsf{b}}\end{aligned}$$

$$\begin{aligned}&\int_S \vec{E}_{\mathsf{a}} \times \vec{H}_{\mathsf{b}} \cdot \vec{n}\,ds \;+\; \int_V \vec{E}_{\mathsf{a}} \cdot \vec{J}_{\mathsf{b}}\,dV \;-\; \int_V \vec{H}_{\mathsf{a}} \cdot \vec{M}_{\mathsf{b}}\,dV \\ &\qquad = \int_S \vec{E}_{\mathsf{b}} \times \vec{H}_{\mathsf{a}} \cdot \vec{n}\,ds \;+\; \int_V \vec{E}_{\mathsf{b}} \cdot \vec{J}_{\mathsf{a}}\,dV \;-\; \int_V \vec{H}_{\mathsf{b}} \cdot \vec{M}_{\mathsf{a}}\,dV\end{aligned}$$

Antenne riceventi



campo irraggiato dall'antenna

campo incidente sull'antenna

a) $\nabla \times \vec{E}_a = -j\omega\mu\vec{H}_a$

$\nabla \times \vec{H}_a = j\omega\epsilon\vec{E}_a$

b) $\nabla \times \vec{E}_b = -j\omega\mu\vec{H}_b$

$\nabla \times \vec{H}_b = j\omega\epsilon\vec{E}_b + \vec{J}_b$

condizioni di radiazione all'infinito

$\vec{n} \times \vec{E}_a = 0$ su S $\vec{n} \times \vec{E}_b = 0$

$$\left.\begin{aligned} \vec{E}_a &= V_a\,\vec{e} \\ \vec{H}_a &= -I_a\,\vec{h} \end{aligned}\right\} \quad \text{sulla porta } S_o \text{ dell'antenna} \quad \left\{\begin{aligned} \vec{E}_b &= V_b\,\vec{e} \\ \vec{H}_b &= I_b\,\vec{h} \end{aligned}\right.$$

$$\int_{\partial V} \vec{E}_a \times \vec{H}_b \cdot \vec{n}\, dS + \int_V \vec{E}_a \cdot \vec{J}_b\, dV = \int_{\partial V} \vec{E}_b \times \vec{H}_a \cdot \vec{n}\, dS$$

$$\int_{S_\circ} \vec{E}_a \times \vec{H}_b \cdot \vec{n}\, dS = V_a\, I_b \qquad\qquad \int_{S_\circ} \vec{E}_b \times \vec{H}_a \cdot \vec{n}\, dS = -V_b\, I_a$$

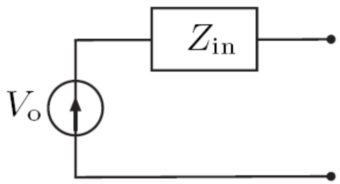
$$\vec{E}_a = \sqrt{\frac{\eta\, P_{in}}{2\,\pi}}\; \frac{e^{-jkr}}{r}\; \sqrt{g}\;\; e^{j\psi}\; \vec{p}$$

$$\int_V \vec{E}_a \cdot \vec{J}_b\, dV = \sqrt{\frac{\eta\, P_{in}}{2\,\pi}} \frac{e^{-jkr}}{r}\; \sqrt{g}\; e^{j\psi}\; \vec{p} \cdot \vec{J}_b\; \Delta V$$

$$\vec{E}_{\rm inc} = -j\eta\; \frac{e^{-jkr}}{2\lambda\, r} \left(\vec{J}_b - \vec{u}_r\; (\vec{J}_b \cdot \vec{u}_r)\right)\; \Delta V$$

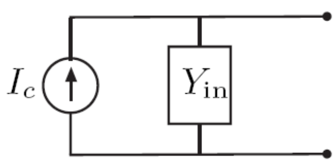
$$V_a\, I_b + V_b\, I_a = \sqrt{\frac{2\, P_{in}}{\eta\, \pi}} \lambda\; \sqrt{g}\; e^{j(\psi - \pi/2)}\; E_{\rm inc}\; \vec{p} \cdot \vec{p}_{\rm inc}$$

circuiti equivalenti di un'antenna ricevente



$$Z_{\text{in}} = R_{\text{in}} + j X_{\text{in}}$$

$$V_0 = \sqrt{\frac{R_{\text{in}}}{\eta\,\pi}}\;\lambda\,\sqrt{g}\;e^{j(\psi_I + \pi/2)}\;E_{\text{inc}}\,\vec{p}\cdot\vec{p}_{\text{inc}}$$



$$Y_{\text{in}} = G_{\text{in}} + j B_{\text{in}}$$

$$I_c = \sqrt{\frac{G_{\text{in}}}{\eta\,\pi}}\;\lambda\,\sqrt{g}\;e^{j(\psi_V - \pi/2)}\;E_{\text{inc}}\,\vec{p}\cdot\vec{p}_{\text{inc}}$$

g guadagno dell'antenna

$\vec{p}$ polarizzazione del campo irraggiato

ψ_V ψ_I termini di fase relativi alla tensione e corrente d'ingresso

i parametri sono valutati nella direzione di provenienza del campo incidente

potenza disponibile alla porta di un'antenna ricevente

$$P_d \quad = \quad \underbrace{\frac{\lambda^2}{4\pi}\, g(\vartheta,\varphi)}_{A_{\mathrm{eff}}(\vartheta,\varphi)} \; \underbrace{\frac{|E_{\mathrm{inc}}|^2}{2\,\eta}}_{W_{\mathrm{inc}}} \; \underbrace{|\,\vec{p}\cdot\vec{p}_{\mathrm{inc}}\,|^2}_{\tau}$$

equazione del collegamento (Friis)

$$P_d \quad = \quad P_{in}\left(\frac{\lambda}{4\pi r}\right)^2 g_{tx}\; g_{rx}\;\; |\,\vec{p}\cdot\vec{p}_{\mathrm{inc}}\,|^2$$