

Antenna Radiation Characteristics

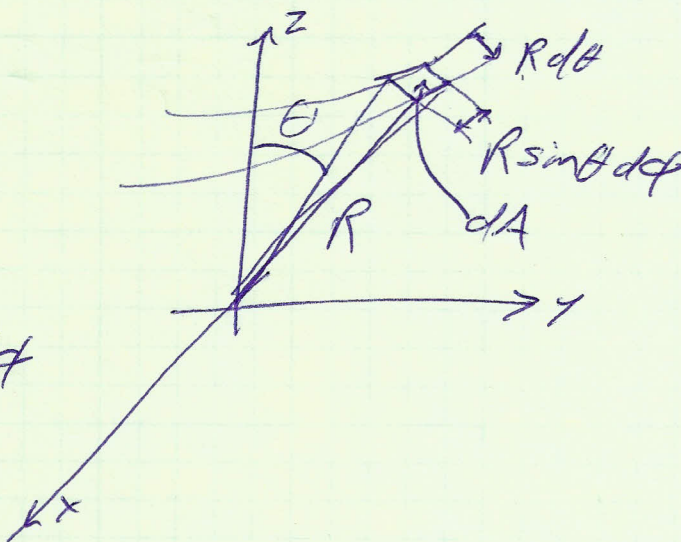
$$dA = R^2 \sin \theta d\theta d\phi$$

$$= R^2 d\Omega$$

$$d\Omega = \frac{dA}{R^2} = \sin \theta d\theta d\phi$$

measured in steradians

one complete sphere has solid angle of 4π Sr



$$dA = R^2 d\Omega$$

$$F(\theta, \phi) = \frac{S(R, \theta, \phi)}{S_{\max}}$$

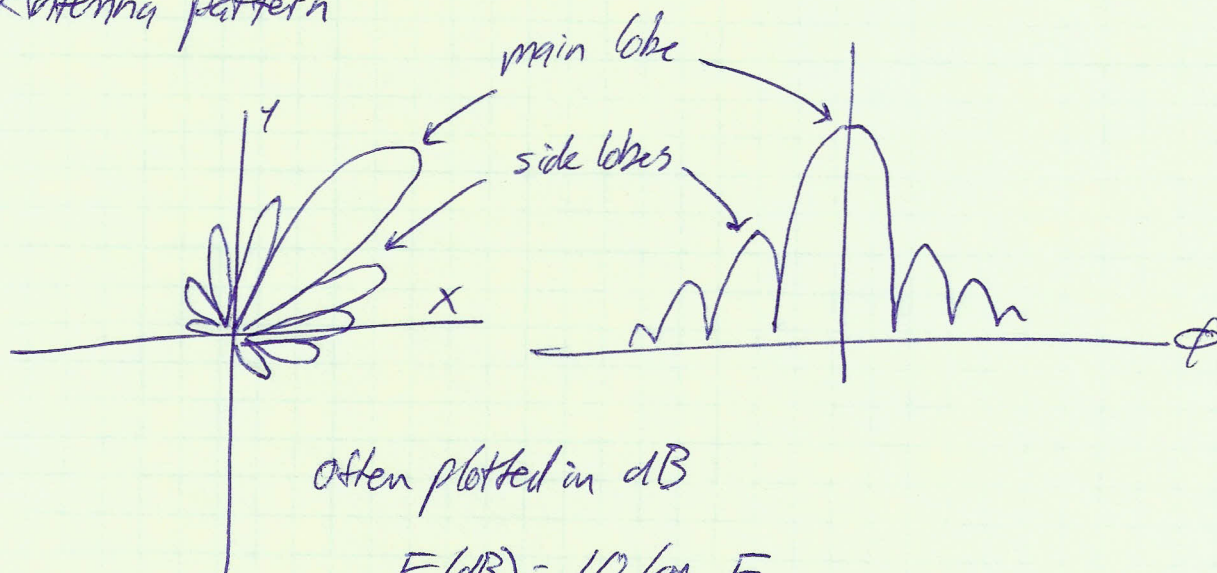
normalized radiation intensity

$$P_{\text{rad}} = R^2 \int_0^{2\pi} \int_0^\pi S(R, \theta, \phi) \sin \theta d\theta d\phi$$

$$= R^2 S_{\max} \int_0^{2\pi} \int_0^\pi F(\theta, \phi) \sin \theta d\theta d\phi$$

$$= R^2 S_{\max} \int_{4\pi} F(\theta, \phi) d\Omega$$

Antenna pattern

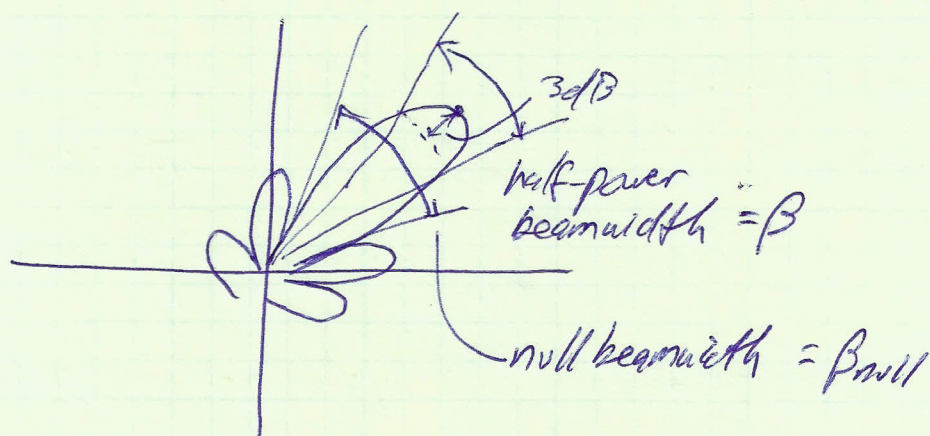


often plotted in dB

$$F(\text{dB}) = 10 \log_{10} F$$

Pattern solid angle

$$\Omega_p = \iint_{4\pi} F(\theta, \phi) d\Omega$$



Directivity

$$D = \frac{F_{\max}}{F_{\text{av}}} = \frac{1}{\frac{1}{4\pi} \iint_{4\pi} F(\theta, \phi) d\Omega} = \frac{4\pi}{\Omega_p}$$

$$D = \frac{4\pi R^2 S_{\max}}{P_{\text{rad}}} = \frac{S_{\max}}{S_{\text{av}}} \quad \left(\text{since } S_{\text{av}} = \frac{P_{\text{rad}}}{4\pi R^2} \right)$$

$$\Omega_p \approx \beta_x \beta_y$$

$$D = \frac{4\pi}{\Omega_p} \approx \frac{4\pi}{\beta_x \beta_y}$$

• Directivity of Hertzian Dipole

$$D = \frac{4\pi}{\iint_{4\pi} F(\theta, \phi) \sin\theta d\theta d\phi} = \frac{4\pi}{\iint_{4\pi} \sin^3\theta d\theta d\phi} = \frac{4\pi}{8\pi/3} = \frac{3}{2}$$

• Antenna Gain

$$\text{efficiency } \mathcal{E} = \frac{P_{\text{rad}}}{P_t}$$

$$\text{Gain } G = \mathcal{E}D$$

• Radiation Resistance

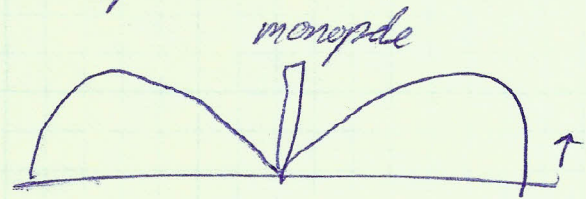
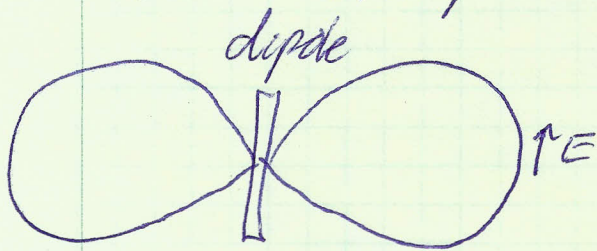
$$Z_{\text{in}} = R_{\text{in}} + jX_{\text{in}}$$

$$P_t = \frac{1}{2} I_0^2 R_{\text{in}}, \quad R_{\text{in}} = R_{\text{rad}} + R_{\text{loss}}$$

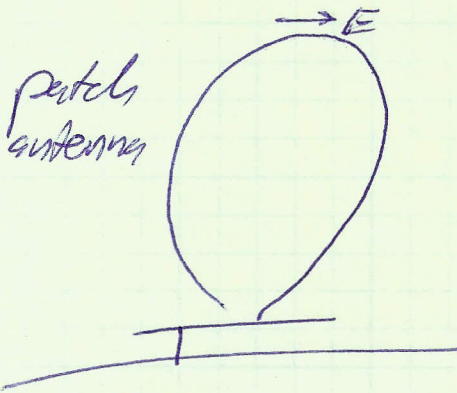
$$P_{\text{rad}} = \frac{1}{2} I_0^2 R_{\text{rad}}, \quad P_{\text{loss}} = \frac{1}{2} I_0^2 R_{\text{loss}}$$

$$\mathcal{E} = \frac{P_{\text{rad}}}{P_t} = \frac{P_{\text{rad}}}{P_{\text{rad}} + P_{\text{loss}}} = \frac{R_{\text{rad}}}{R_{\text{rad}} + R_{\text{loss}}}$$

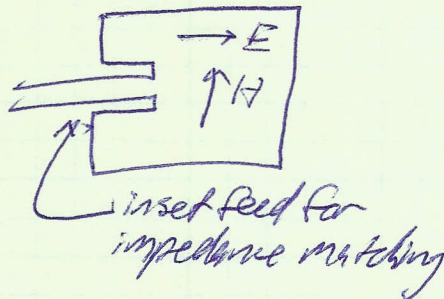
Some radiation patterns of typical antennas



radiation at horizon depends on
size and resistance of ground plane



patch antenna



slot antenna

