Phys 221

Lecture 33

Assign #12. p. 374
10.3, 10.5, 10.11, 10.14.

Ref. 10-3, 4.

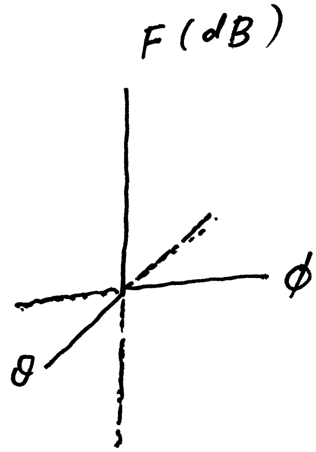
- Antenna pattern
  - described by normalized radiation intensity

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

For a Hertzian dipole: $F(\theta, \phi) = \sin^2\theta$.

- How to plot $F(\theta, \phi)$
  - 3D.

(Fig. 10-10 On page 357)



$$F(dB) = 10 \log F$$

Note: A maximum: $F(dB) = 0$

$\because$ $F_{max} = 1$.

– 2D .

a) Polar diagram

(F, θ) and (F, ϕ)

↑ radial ↑ angular . ↑ don't need it when it's symmetrical (like the Hertzian dipole)

fig.10-11 (a) . p.358

b) . Rectangular plot

(θ, F) and (ϕ, F) .

↑ x ↑ y .

• Beamwidth (at half-power or 3-dB)

$\beta = \Delta\theta = \theta_2 - \theta_1$ (θ_1 and θ_2

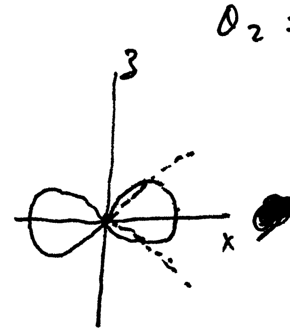
e.g. Hertzian dipole . $F(\theta, \phi) = \sin^2\theta = F(\theta)$

$F_{max} = 1$.

3-dB points: $\sin^2\theta = \frac{1}{2}$, $\theta_1 = 45°$,

$\theta_2 = 135°$.

$\therefore \beta = 135° - 45° = 90°$.



- Directivity

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

$$\Omega_p = \iint_{4\pi} F(\theta,\phi)\, d\Omega$$ — pattern solid angle.

e.g. For an isotropic antenna, $F(\theta,\phi) = 1$.

$$\Omega_p = 4\pi.$$

$$D = 1.$$

(No special direction at all!)

e.g: Hertzian dipole. $F(\theta,\phi) = \sin^2\theta = F(\theta)$

Pattern solid angle $\Omega_p = \iint_{4\pi} \sin^2\theta \cdot \sin\theta \cdot d\theta\, d\phi$

$$= \int_{\phi=0}^{2\pi} \int_{\theta=0}^{\pi} \sin^3\theta\, d\theta \cdot d\phi$$

$$= \frac{8\pi}{3}.$$

$$D = \frac{4\pi}{8\pi/3} = \frac{3}{2} = 1.5.$$

- Radiation efficiency

$$\xi = \frac{P_{rad}}{P_t} = \frac{\text{Power radiated into space}}{\text{transmitter power}}.$$

- Antenna gain.

$$G = \frac{4\pi R^2 S_{max}}{P_t}$$

$$G = \xi D.$$

Since:

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

$$= R^2 S_{max} \cdot \Omega_p.$$

$$D = \frac{4\pi}{\Omega_p}.$$

- Radiation resistance : R_{rad} : $\frac{1}{2} R_{rad} \cdot I_0^2 = P_{rad}$.

I_0: amplitude.

$$P_t = P_{rad} + P_{loss}$$

P_t: Transmitter power. supplied by generator

P_{rad}: power radiated into space

P_{loss}: power dissipated as heat in antenna.

- loss resistance R_{loss}:

$$\frac{1}{2} I_0^2 R_{loss} = P_{loss}.$$

e.g. A Hertzian dipole : $l = 0.04\ m$, $f = 75\ MHz = 7.5 \times 10^7\ Hz$.

copper $\sigma_c = 5.8 \times 10^7\ S/m$.

radius $a = 0.4\ mm = 4 \times 10^{-4}\ m$.

find: R_{loss}, R_{rad}. and ξ

$$R_{loss} = \frac{l}{\sigma_c \delta_s 2\pi a} \qquad \delta_s \approx \sqrt{\pi f \mu_c \sigma_c}.$$

$$= \frac{l}{2\pi a} \sqrt{\frac{\pi f \mu_c}{\sigma_c}} = 0.036\ \Omega.$$

for R_{rad}:

$$P_{rad} = \frac{4\pi R^2}{D} S_{max}. \qquad \left(S_{max} = \frac{15\pi I_0^2}{R^2} \left(\frac{l}{\lambda}\right)^2 \right)$$

$D = 1.5$

$$= 40\pi^2 I_0^2 \left(\frac{l}{\lambda}\right)^2$$

compare to : $P_{rad} = \frac{1}{2} I_0^2 R_{rad}$.

$$\therefore R_{rad} = 80\pi^2 \left(\frac{l}{\lambda}\right)^2 . = 0.08\ \Omega$$

$$\xi = \frac{P_{rad}}{P_t} = \frac{P_{rad}}{P_{rad} + P_{loss}} = \frac{\frac{1}{2} I_0^2 R_{rad}}{\frac{1}{2} I_0 R_{rad} + \frac{1}{2} I_0 R_{loss}}$$

$$= \frac{R_{rad}}{R_{rad} + R_{loss}}$$

$$= 0.69.$$