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Far field $\Rightarrow$ $E_r, H_r = 0$, $\vec{F} = 0$

$$E_\phi = -\eta_0 H_\theta = -jk\eta_0 A_\phi = 0$$

$$E_\theta = -jk\eta_0 A_\theta = \eta_0 H_\phi = -jk\eta_0 \frac{e^{-jkr}}{4\pi r} I_0 L(-\sin\theta)\frac{\sin(\psi(\theta))}{\psi(\theta)}$$

(compare this to eq 4-10b in the text....)

Maximum Radiation ?:

$f(\theta, r)$ but not $f(\phi)$

$\theta = 90$ for E_{max}, $\theta = 0$ for E_{min}.

Power density (Intensity)

$$\frac{1}{2}\vec{P} = \frac{1}{2}\vec{E}\times\vec{H}^* = \frac{E_\theta E_\theta^*}{\eta_0}\underbrace{(\hat{\theta}\times\hat{\phi})}_{\hat{r}\ \text{direction}}$$

$$\vec{E} = E_\theta\hat{\theta} \qquad \vec{H} = H_\phi\hat{\phi} = \frac{E_\theta}{\eta_0}\hat{\phi}$$

$$\frac{1}{2}\vec{P} = \hat{r}\frac{1}{2}\left(\frac{k\eta_0}{4\pi r}\right)^2 (I_0 L)^2 \sin^2\theta\left[\frac{\sin\psi(\theta)}{\psi(\theta)}\right]^2 \ \text{w/m}^2$$

Normalized field Pattern:

$$E_n(\theta,\phi) = \frac{E(\theta,\phi)}{E_{max}}$$

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$$E_{max} = E_o(\theta = 90^\circ) = \frac{j k \eta_o e^{-jkr}}{4\pi r} I_o L$$

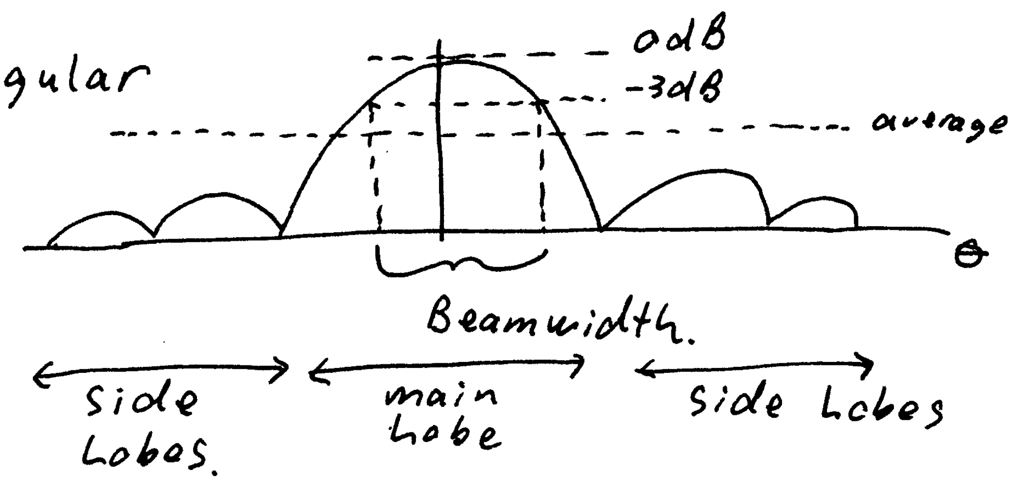
$$E_n(\theta) = \sin\theta \, \frac{\sin(\psi(\theta))}{\psi(\theta)} \qquad \psi(\theta) = \frac{KL\cos\theta}{2}$$

Normalized Power pattern

$$P_n(\theta) = |E_n(\theta)|^2 = \sin^2\theta \left[\frac{\sin\psi(\theta)}{\psi(\theta)}\right]^2$$

There are two common ways the display this graphical data.

Rectangular



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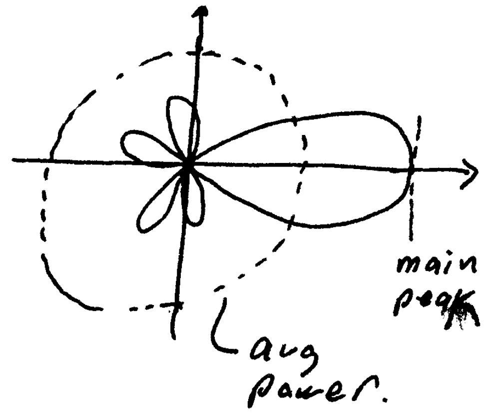
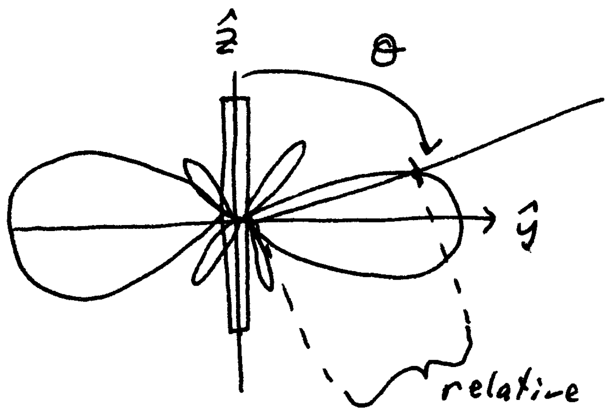
"Directivity" i.e. focusing Power of the Antenna

$$D \triangleq \frac{\text{Main Peak power}}{\text{Average Power.}}$$



Polar Plot.



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$$D = \frac{P_{max}}{\underbrace{\frac{1}{4\pi}\int_0^{2\pi} d\phi \int_0^{\pi} d\theta \sin\theta \left[P(\theta,\phi) \right]}_{P_{avg} \Rightarrow \text{isotropic}}}$$

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Example: short dipole $L << \lambda$

$$\psi(\theta) = \frac{kL\cos\theta}{2} \qquad k = \frac{2\pi}{\lambda} \Rightarrow \psi(\theta) = \frac{L\pi}{\lambda}\cos\theta << 1$$

note: the above approx gives eq 4-10b in text

$$P(\theta) = \sin^2\theta \ \frac{\sin\psi}{\psi} \cong \sin^2\theta \quad \text{(as in text)}$$

$$D = \frac{P_{max}}{P_{avg}} = \frac{1}{\frac{1}{4\pi}\int_0^{2\pi} d\phi \int_0^{\pi} d\theta \sin\theta \left[\sin^2\theta\right]}$$

$$D_{short} = \frac{3}{2} = 1.76\,dBi \quad \text{(eq 4-31 txt)}$$

max D occurs when $L = \frac{\lambda}{2}$

$$D_{\lambda/2} = 1.64 = 2.15\,dBi$$

Comparing $D_{short} - D_{\lambda/2} = 1.76 - 2.15 = -0.39\,dB$

$\Rightarrow$ why not just use a short dipole?

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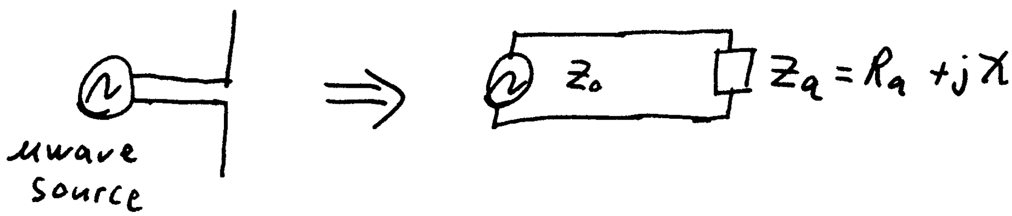
Feed point Z for a dipole:



$R_a = R_r + R_{ohmic}$

R_{ohmic} — heat dissipation - bad

R_r — radiation - good

$$P_r = \frac{1}{2}\iint (\vec{E} \times \vec{H}^*)\, d\vec{s} = \frac{1}{2}|I_n|^2 R_r$$

$$P_\Omega = \frac{1}{2}|I_r|^2 R_{ohmic}$$ (see 4-18 text)

Loss due to feed Line Reflection.

$$\Gamma = \frac{Z_a - Z_o}{Z_a + Z_o}$$

$|\Gamma|^2 \Rightarrow$ the fraction of the incident power from the transmitter lost due to reflection at the antenna terminals.

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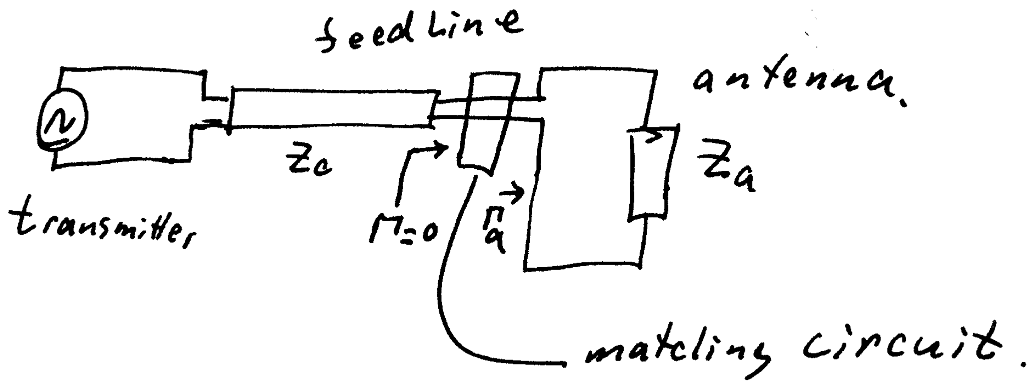
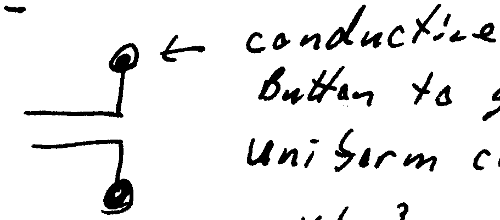


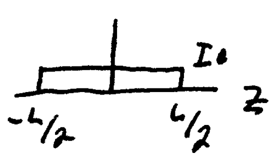
A matching circut is used to eliminate the reflection Loss. The does not remove the R_{ohmic} Loss.

Input impedance -

"real" short dipole

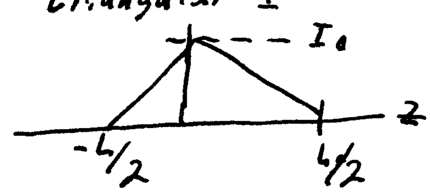


uniform I



$$R_r = 80\pi^2 \left|\frac{L}{\lambda}\right|^2$$

triangular I



$$R_r = 20\pi^2 \left|\frac{L}{\lambda}\right|^2.$$

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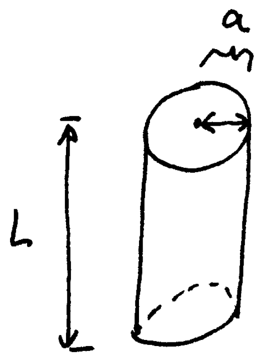
R_{ohmic} ⇒ most conduction occurs at the outer surface – "skin effect"



Surface resistance.

$$R_s = \sqrt{\frac{\omega \mu}{2\sigma}}$$

σ = surface conductivity

$\sigma = 5.7 \times 10^7$ ℧/m for copper.

note: surface cond is different than bulk conductivity – – (but usually ok)

for uniform I_o:

$$R_\Omega = \frac{R_s L}{2\pi a}\ \Omega.$$

for short dipole:

$$R_\Omega = \frac{R_s L}{6\pi a}$$

Antenna effeciency: $\eta = \dfrac{P_r}{P_r + P_\Omega} = \dfrac{R_r}{R_r + R_\Omega}.$

assumes $\Gamma = 0$

no reflection or

miss-match Loss

(September 26- no class)