

# Antennas

EEGR 6316

Fall 2012

# Radiation

- Moving charges create electric and magnetic fields.
- Potential vector:  $A(r') = \int \mu J(r') G(r', r) dV'$
- Green's function:  $G(r', r) = \frac{e^{-\beta|r'-r|}}{4\pi|r'-r|}$
- Distance from source to origin:  $r'$
- Distance from origin to observation point:  $r$

# Antennas

- Approach:

- $J \rightarrow A \rightarrow B \rightarrow H \rightarrow E \rightarrow S$

- $J \rightarrow A \quad A(r') = \int \mu J(r') G(r', r) dV'$

- $A \rightarrow B \quad B = \nabla \times A$

- $B \rightarrow H \quad B = \mu H$

- $H \rightarrow E \quad E = \frac{i}{\omega \epsilon} (\nabla \times H)$

- $E \rightarrow S \quad S = E \times H$

# Dipole Antenna

- Current distribution  $J(r) = Idl \cos(\omega t) \delta(r)$

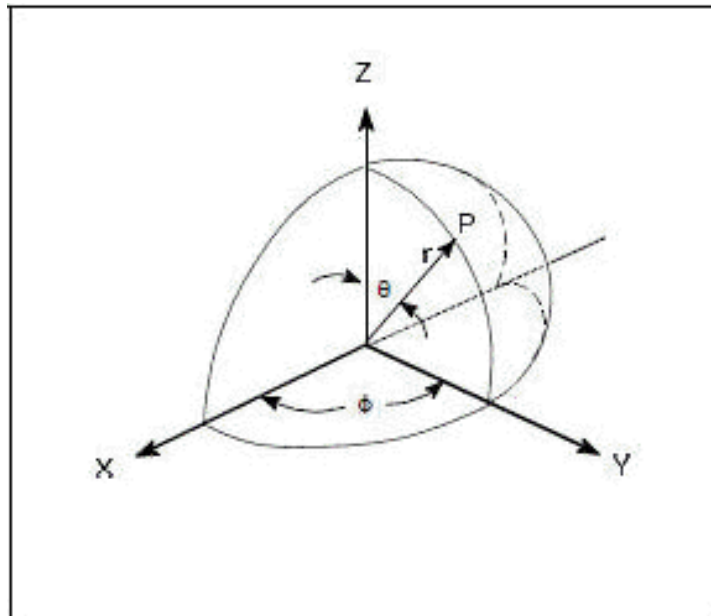


Figure 1 - Spherical Radiation to point "P" from an ideal point source.

- A dipole is an idealized radiator with infinitesimal height.

# Dipole Antenna

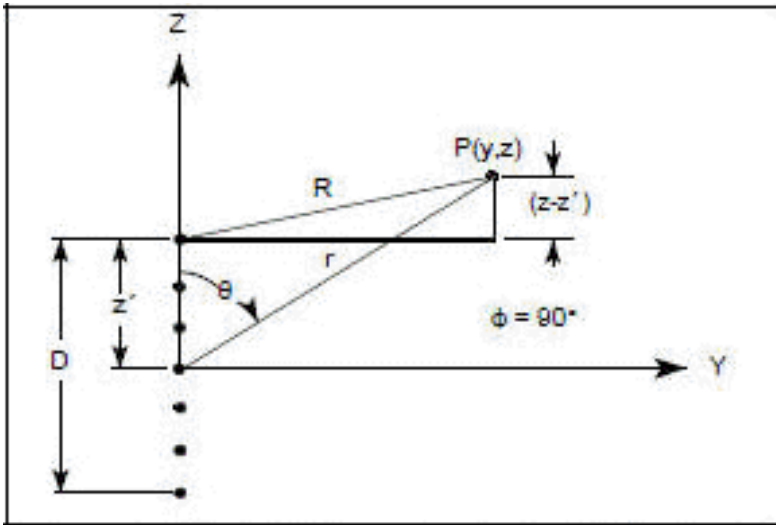


Figure 2 - Near Field Geometry of point "P" for a non-ideal radiator with dimension  $D$ .

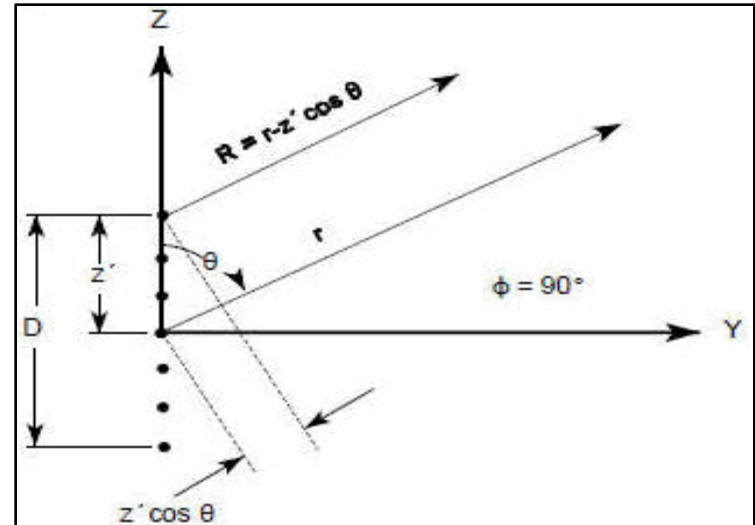
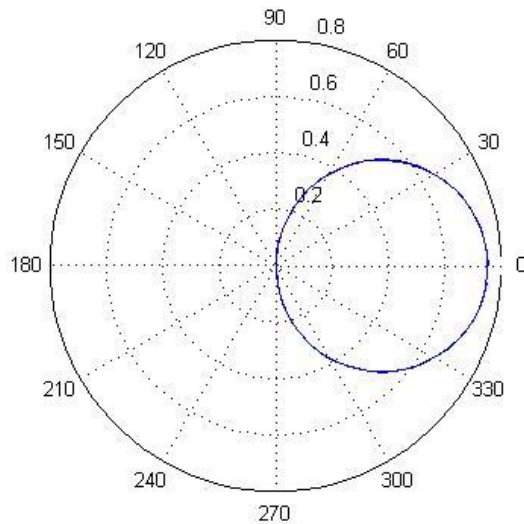


Figure 3 - Far Field Parallel Ray Approximation for Calculations

The Near Field is within one wavelength of the radiator and contains all the components of the fields, regardless of the order of  $(1/r)$ . For the far field, the components of an order higher than  $(1/r)$  are negligible. The equations herein represent the far field expressions.

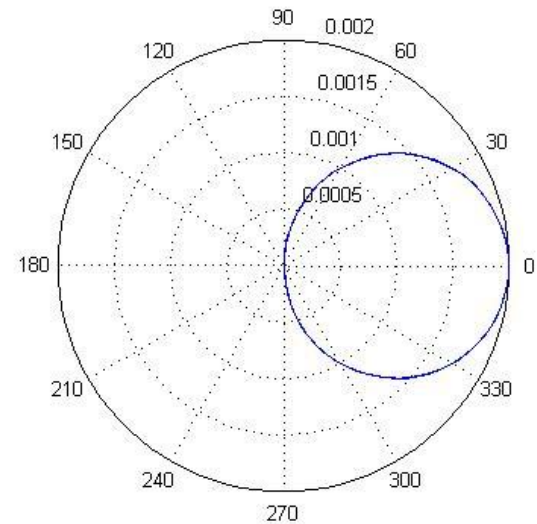
# Dipole Antenna

Electric Field



$$E_{\theta} = \frac{Idl \sin \theta}{4\pi\epsilon} \left[ \frac{-\omega \sin \omega t'}{rv^2} \right]$$

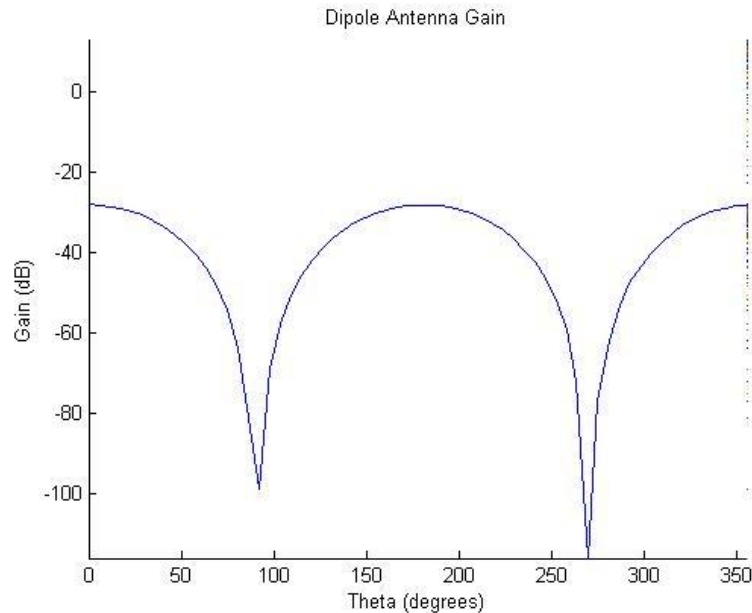
Magnetic Field



$$H_{\phi} = \frac{Idl \sin \theta}{4\pi} \left[ \frac{-\omega \sin \omega t'}{rv} \right]$$

# Dipole Antenna

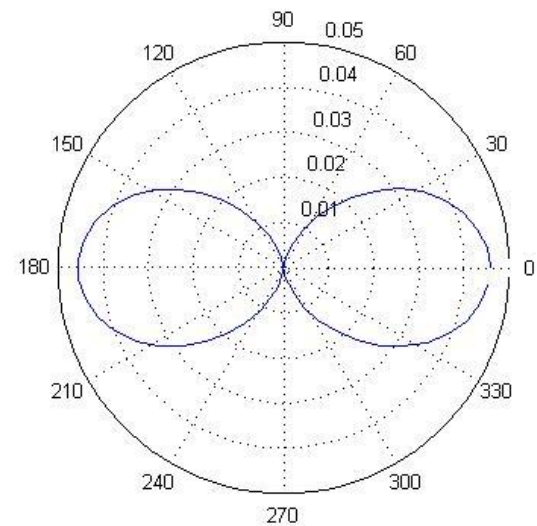
## Gain of a Dipole Antenna



$$Gain = 4\pi \frac{\langle S \rangle}{\langle P \rangle}$$

$$\langle P \rangle = \frac{I^2 dl^2 \omega^2}{12\pi c^3 \epsilon}$$

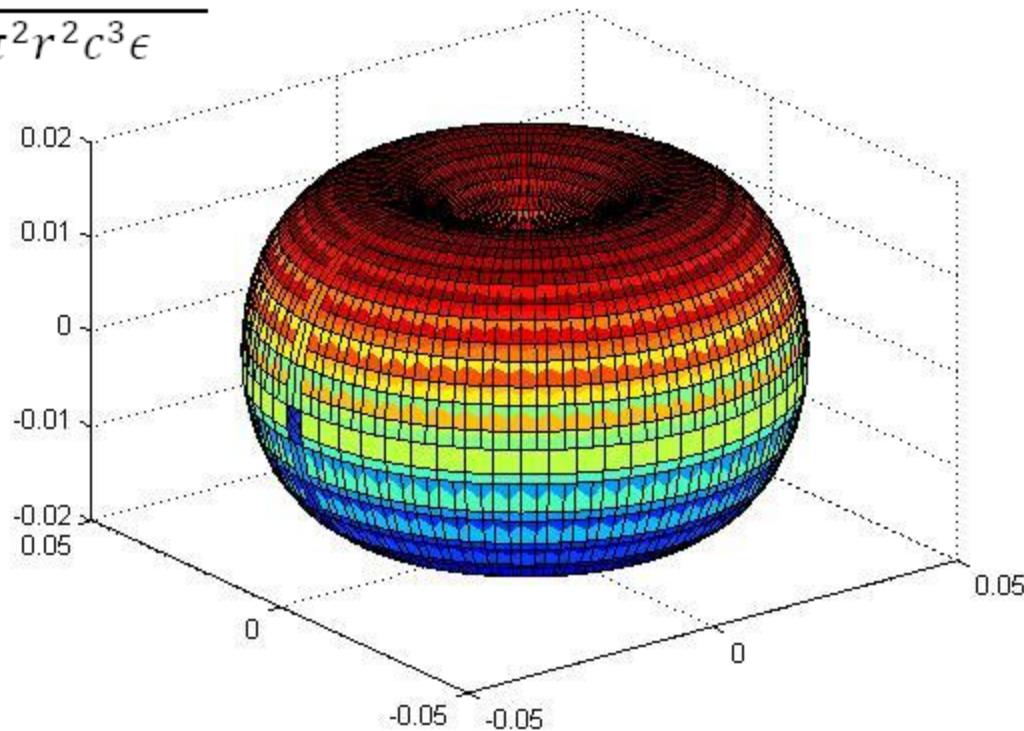
## 2D Radiation Pattern of Dipole



$$\langle S \rangle = \frac{\omega^2 I^2 dl^2 (\sin \theta)^2}{32\pi^2 r^2 c^3 \epsilon}$$

# Radiation Pattern of a Dipole Antenna

$$\langle S \rangle = \frac{\omega^2 I^2 dl^2 (\sin \theta)^2}{32 \pi^2 r^2 c^3 \epsilon}$$



The dipole antenna radiates consistently in the azimuth, but as elevation increases, the intensity drops off considerably until directly above or below the dipole there is zero field strength.

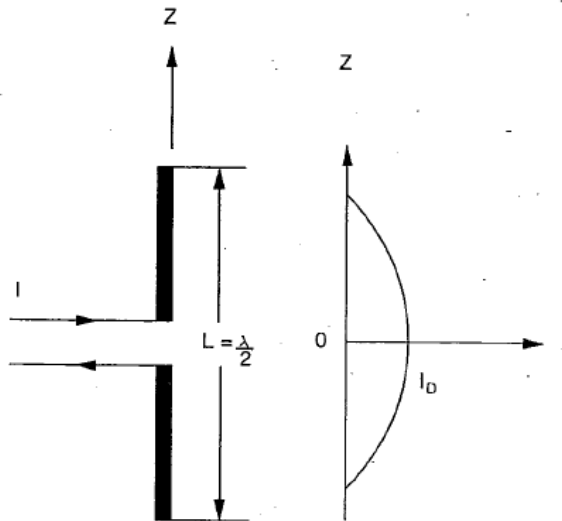


# Half Wave Antenna

- A half-wave antenna has a length half of one wavelength of the operating frequency. The same approach is used to solve a half-wave as a dipole antenna.

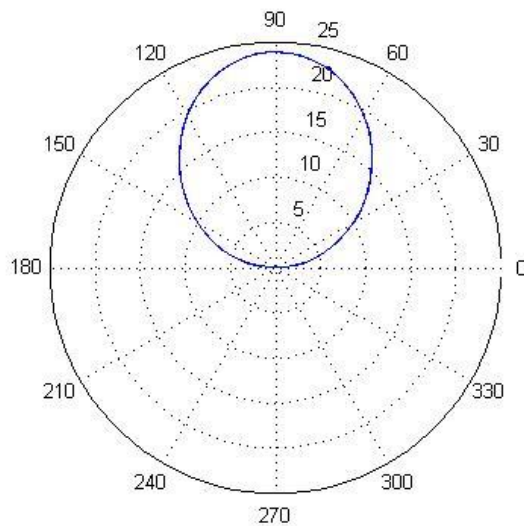
- Current distribution

$$J(r) = \begin{cases} I_m \sin\left(\beta \left[\frac{\lambda}{4} - z\right]\right) & \text{if } z > 0 \\ I_m \sin\left(\beta \left[\frac{\lambda}{4} + z\right]\right) & \text{if } z < 0 \end{cases}$$



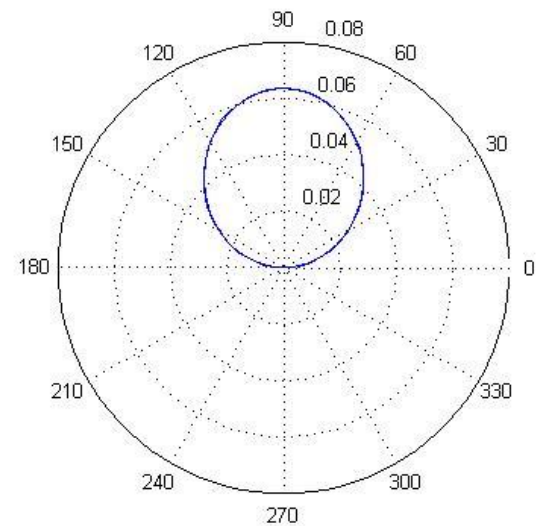
# Half Wave Antenna

Electric Field



$$E_{\theta} = \eta H_{\varphi}$$

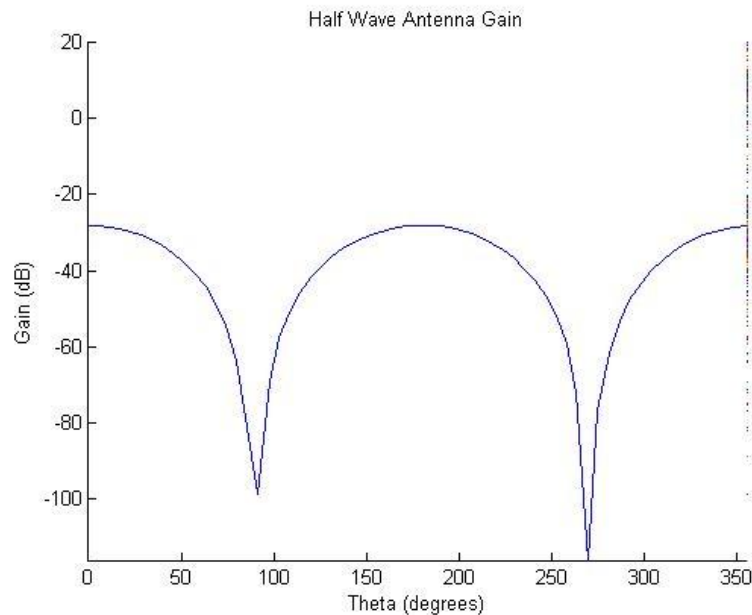
Magnetic Field



$$H_{\varphi} = \frac{jI_m e^{j\beta r}}{2\pi r} \frac{\cos(\frac{\pi}{2} \cos \theta)}{\sin \theta}$$

# Half Wave Antenna

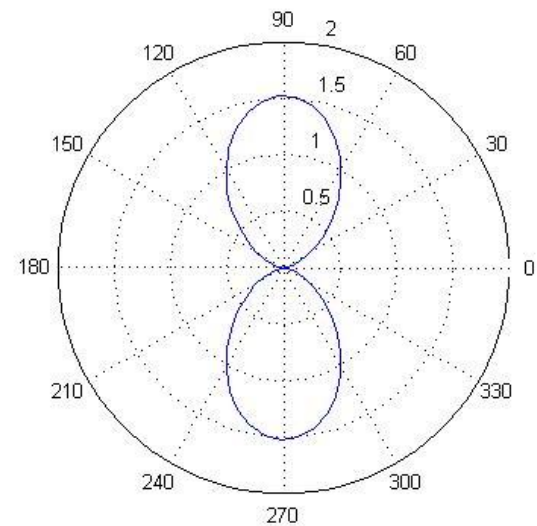
## Gain of a Half Wave Antenna



$$Gain = 4\pi \frac{\langle S \rangle}{\langle P \rangle}$$

$$\langle P \rangle = \frac{.609\eta I_m^2}{2\pi}$$

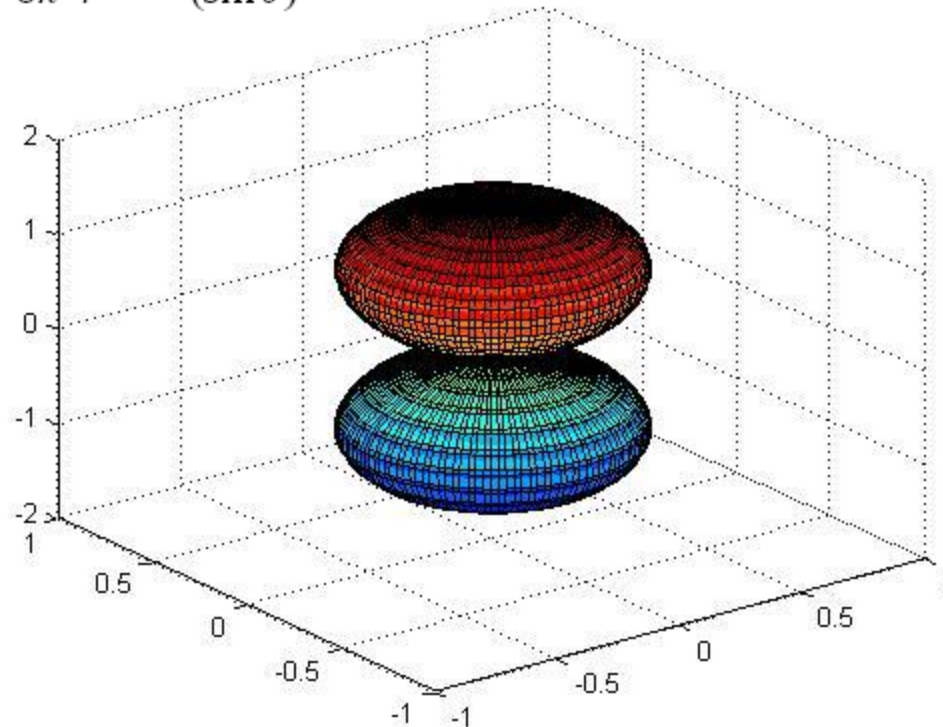
## 2D Radiation Pattern of a Half Wave



$$\langle S \rangle = E_{\theta} H_{\phi} = \frac{\eta I_m^2}{8\pi^2 r^2} \frac{(\cos(\frac{\pi}{2} \cos \theta))^2}{(\sin \theta)^2}$$

# Radiation Pattern of a Half Wave Antenna

$$\langle S \rangle = E_{\theta} H_{\phi} = \frac{\eta I_m^2}{8\pi^2 r^2} \frac{(\cos(\frac{\pi}{2} \cos \theta))^2}{(\sin \theta)^2}$$



The intensity of the half wave antenna is weaker at zero elevation in comparison to the dipole antenna. This can be seen in the phase change (sine instead of cosine) of the electric and magnetic fields in the previous slide.

# References

- N. N. Rao, Fundamentals of Electromagnetics for Engineering, Pearson .
- C. A. Balanis, Advanced Engineering Electromagnetics, Hoboken: John Wiley & Sons, Inc., 1989.
- R. Cafe, "Antenna Near Field," 17 December 2012. [Online]. Available: <http://www.rfcafe.com/references/electrical/ew-radar-handbook/antenna-near-field.htm>. [Accessed 19 December 2012].