Fields and Waves I

Lecture 26
Intro to Antennas & Propagation

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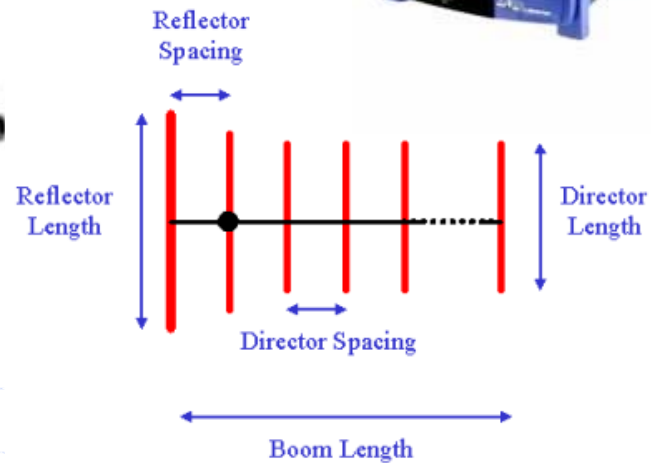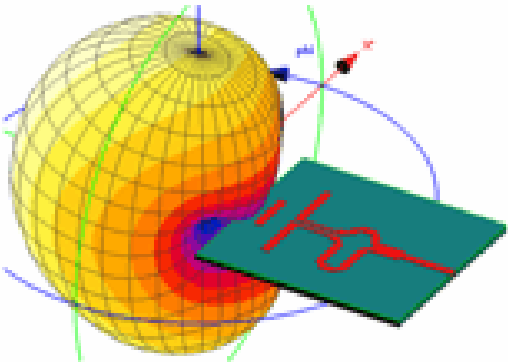Rensselaer Polytechnic Institute, Troy, NY

These Slides Were Prepared by Prof. Kenneth A. Connor Using Original Materials Written Mostly by the Following:

- Kenneth A. Connor – ECSE Department, Rensselaer Polytechnic Institute, Troy, NY
- J. Darryl Michael – GE Global Research Center, Niskayuna, NY
- Thomas P. Crowley – National Institute of Standards and Technology, Boulder, CO
- Sheppard J. Salon – ECSE Department, Rensselaer Polytechnic Institute, Troy, NY
- Lale Ergene – ITU Informatics Institute, Istanbul, Turkey
- Jeffrey Braunstein – Chung-Ang University, Seoul, Korea

Materials from other sources are referenced where they are used.
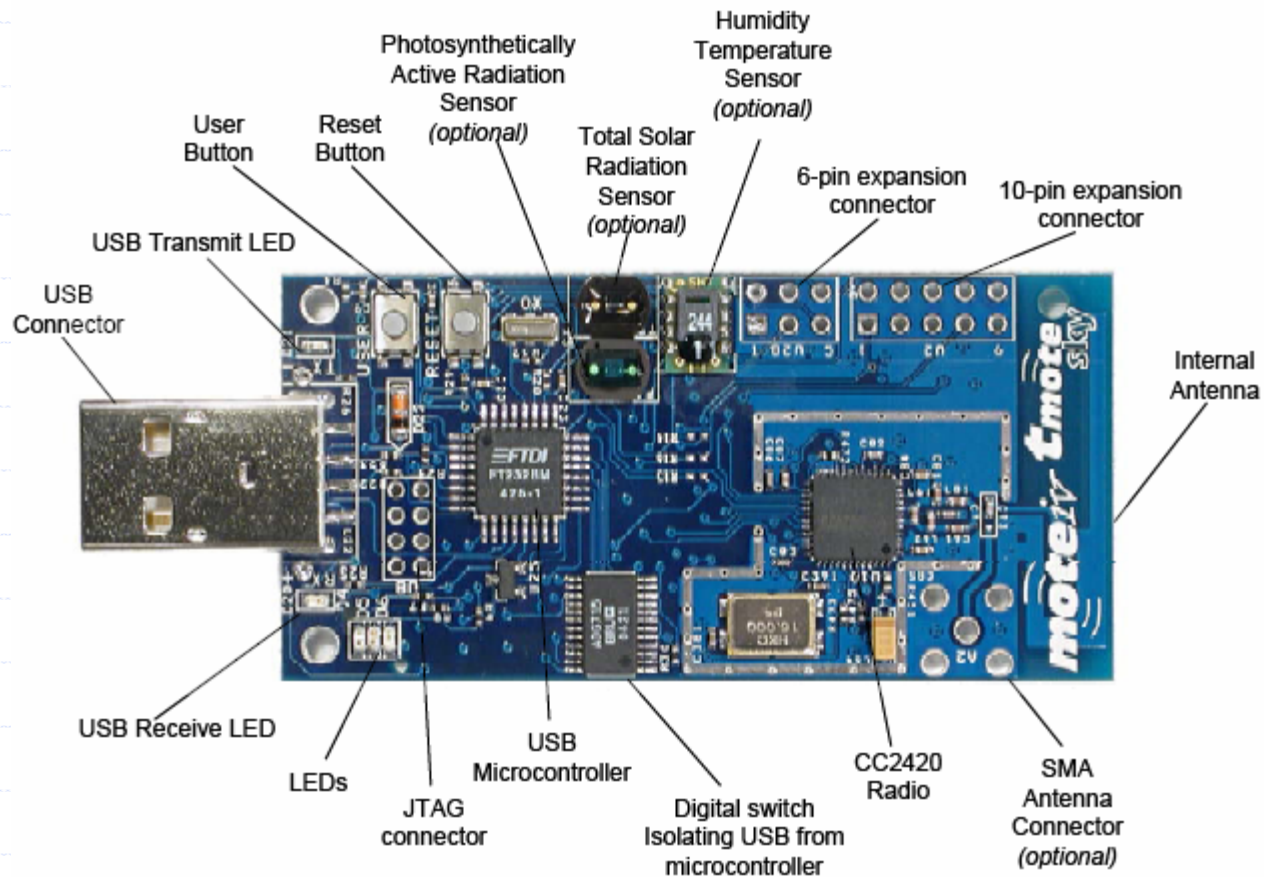Those listed as Ulaby are figures from Ulaby's textbook.

Examples of Antennas

Reflector
Spacing

Reflector
Length

Director
Length

Director Spacing

Boom Length

Antennas

mote*iv* Tmote Sky

Inverted F Antenna

- Photosynthetically Active Radiation Sensor *(optional)*
- Humidity Temperature Sensor *(optional)*
- User Button
- Reset Button
- Total Solar Radiation Sensor *(optional)*
- 6-pin expansion connector
- 10-pin expansion connector
- USB Transmit LED
- USB Connector
- Internal Antenna
- USB Receive LED
- LEDs
- JTAG connector
- USB Microcontroller
- Digital switch Isolating USB from microcontroller
- CC2420 Radio
- SMA Antenna Connector *(optional)*

mote*iv* Tmote Sky

Texas Instruments MSP430 F1611 microcontroller

48-bit silicon serial ID

2-pin SVS connector

USB Flash (2kB)

32kHz oscillator

ST Code Flash (1MB)

mote*iv* Tmote Sky

Measured Output Power

The RF output power of the Tmote Sky module from the CC2420 radio is shown in Figure 9. For this test, the Tmote Sky module is transmitting at 2.405GHz (IEEE 802.15.4 channel 11) using the O-QPSK modulation with DSSS. The CC2420 programmed output power is set to 0 dBm. The measured output power of the entire modulated spectrum is 2.4 dBm.
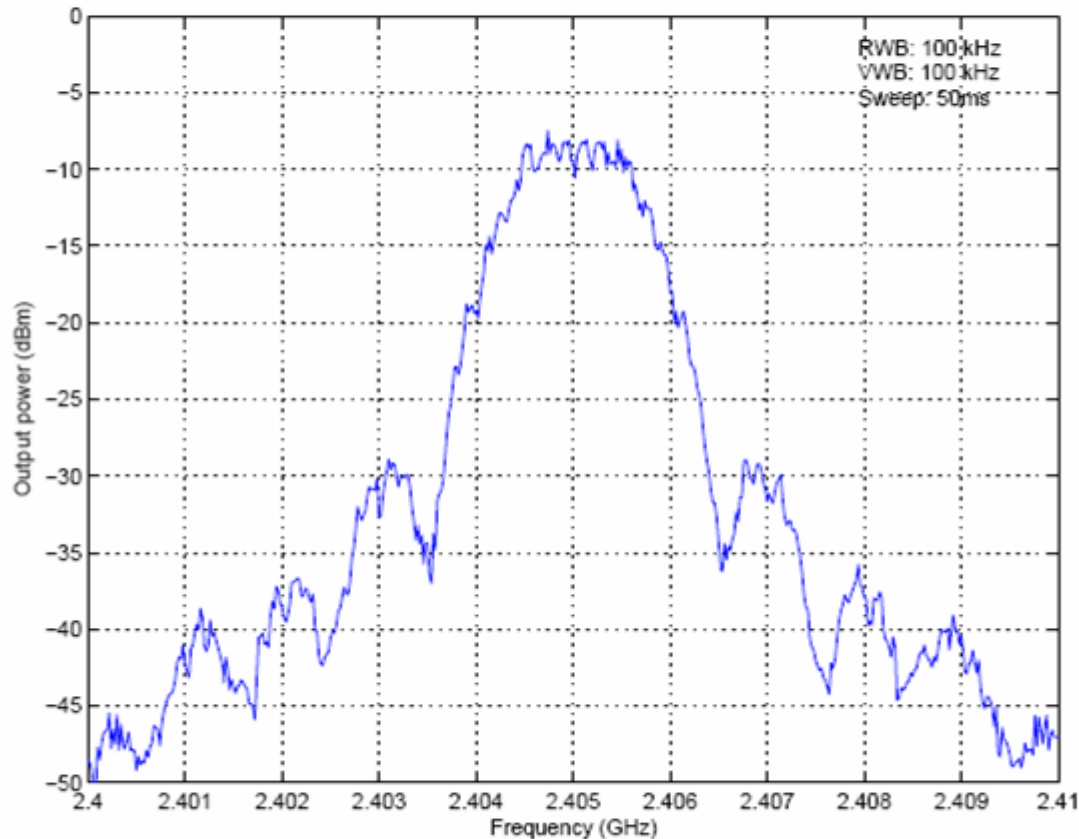
Figure 9 : Measured RF output power over the modulated spectrum from the Tmote Sky module

mote*iv* Tmote Sky

Radiation Pattern

Ref.no: 18-12-03

CF 2442.000 MHz
4 dB/ div
Ref Lev: _____ dBm

Horisontal Polarization
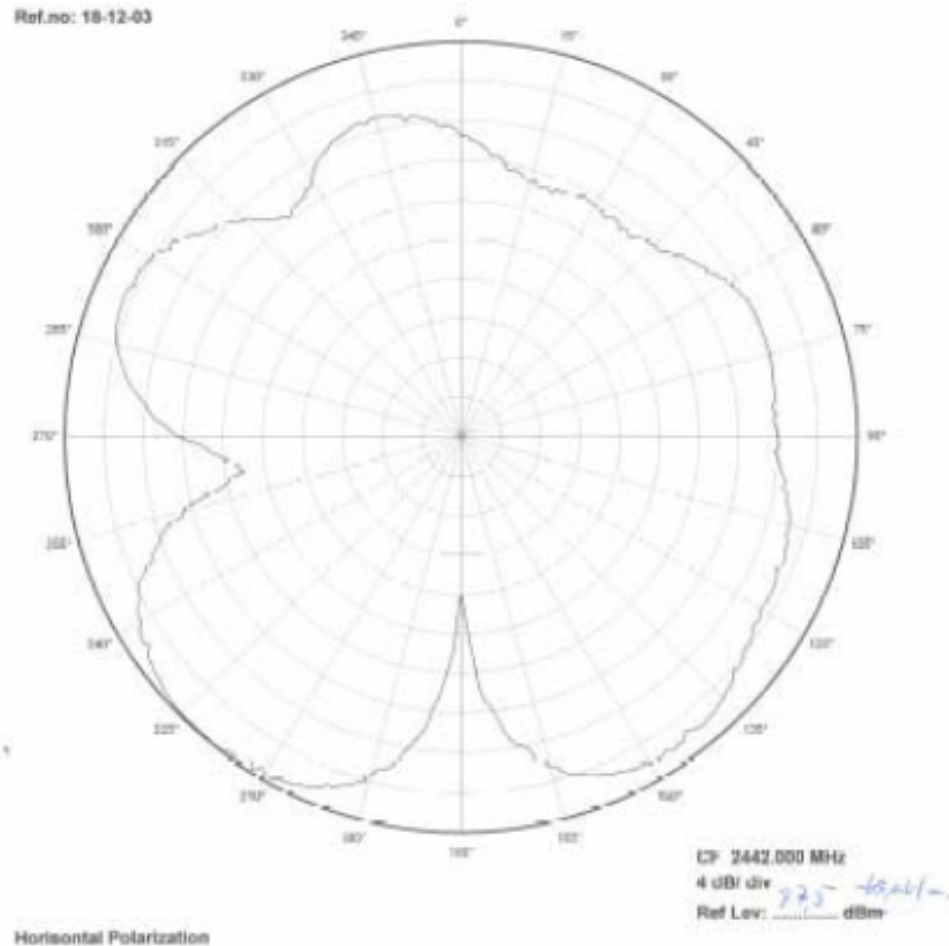
Figure 12 : Radiated pattern of the Inverted-F antenna with horizontal mounting (from Chipcon AS)

mote*iv* Tmote Sky

Ref.no: 18_12_03

CF 2442.000 MHz
5 dB/ div
Ref Lev: _70_ dBm

Horisontal Polarization
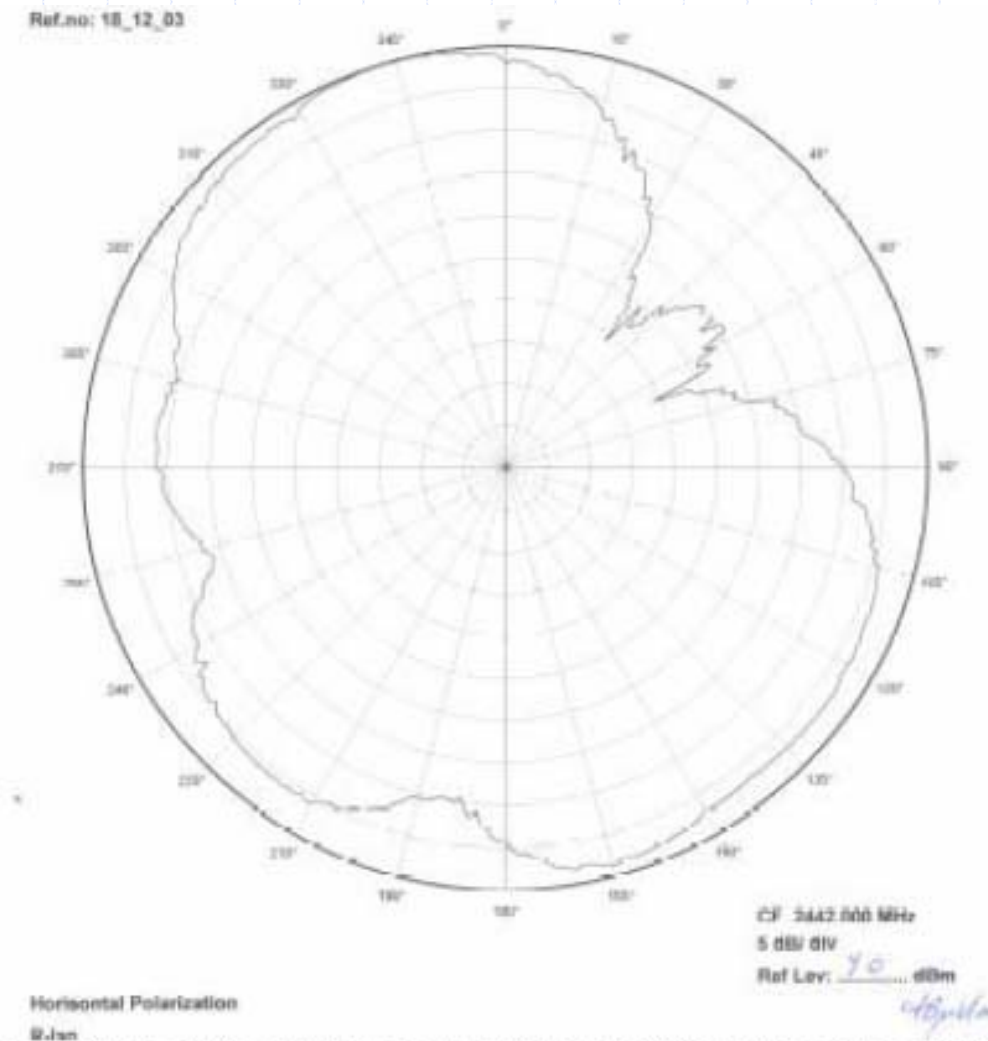
Figure 13 : Radiated pattern of the Inverted-F antenna with vertical mounting (from Chipcon AS)
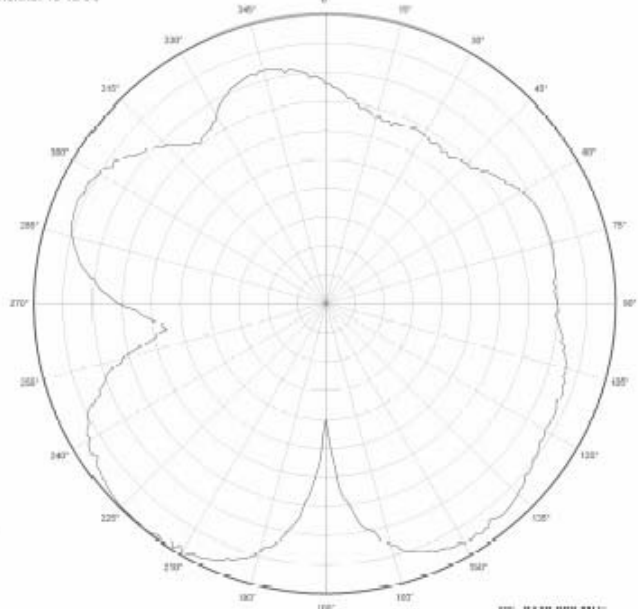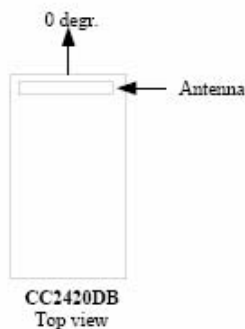
Figure 3: Radiated pattern horizontal mounting

Figure 3 depicts the antenna pattern while the CC2420DB is mounted horizontally with the antennas parallel section aligned to the 0 degree direction.
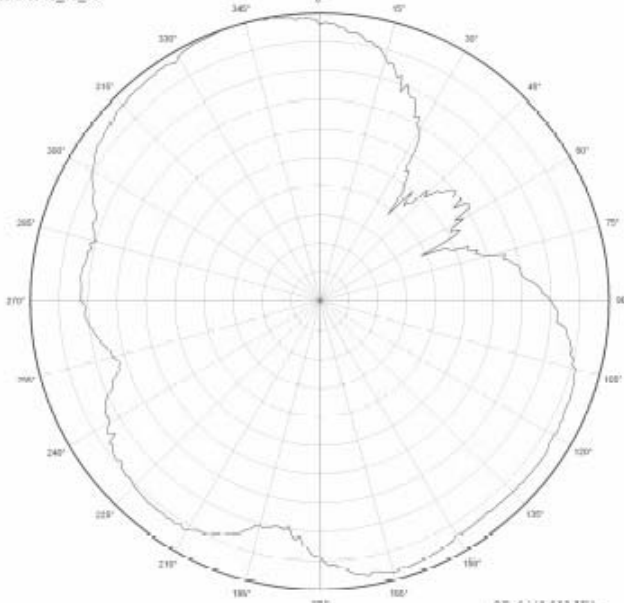
Figure 4: Radiated antenna pattern vertical mounting

Figure 4 depicts the antenna pattern while the CC2420DB is mounted vertically with the antennas parallel section aligned to the 0 degree direction.

The peak antenna gain is −5 dBi, the corresponding peak field strength is 90dBuV/m.

Transmission Lines & Antennas

- Review Transmission Lines
- Review Boundary Conditions
- Review Voltage, Current, Electric and Magnetic Fields
- Etc.

TEM Waves on Transmission Lines

Connecting Uniform Plane Waves with Voltages and Currents on Transmission Lines:

$$E_x(z) = E_+ e^{-j\beta z} + E_- e^{+j\beta z}$$

$$H_y(z) = \frac{E_+ e^{-j\beta z} - E_- e^{+j\beta z}}{\eta}$$
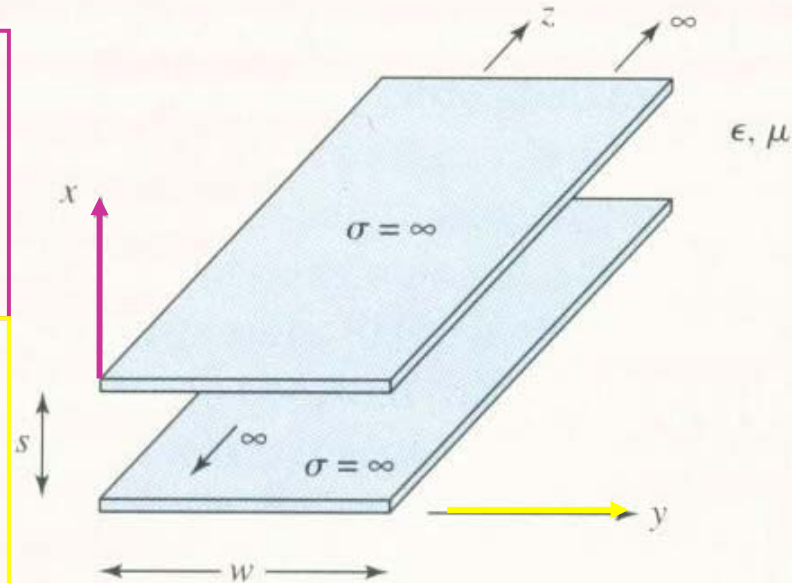
TEM Waves

These fields can exist in the region between the conducting plates if the boundary conditions on the plates are reasonably satisfied. Since the electric field has only an *x* component, it is totally normal to the conducting boundaries. This can occur if there is a surface charge on the boundary,

$$\rho_s = \varepsilon E_x(z) = \varepsilon E_+ e^{-j\beta z} + \varepsilon E_- e^{+j\beta z}$$

The magnetic field is totally tangent to the conducting boundary, which can occur if there is a surface current density given by

$$J_s = H_y(z) = \frac{E_+ e^{-j\beta z} - E_- e^{+j\beta z}}{\eta}$$

TEM Waves

Then, assuming that the lower plate is grounded, the voltage on the upper plate will be

$$v(z) = \int_0^s E_x(z)dx = sE_+e^{-j\beta z} + sE_-e^{+j\beta z} = V_+e^{-j\beta z} + V_-e^{+j\beta z}$$

where we have integrated the electric field along the vertical (red) path shown.
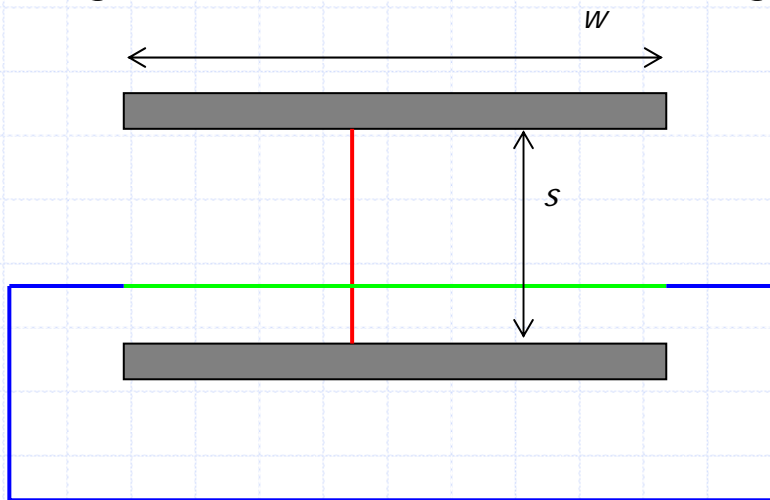
TEM Waves

To connect the magnetic field with the current, we must integrate along a closed path that encloses one of the two conductors. The bottom path shown includes the horizontal (green) path inside the field region and the blue path outside of the field region. (We assume no fringing in this ideal case.) The magnetic field only contributes along the green path. Thus

$$i(z) = \int_0^w H_y(z)dy = \frac{wE_+e^{-j\beta z} - wE_-e^{+j\beta z}}{\eta}$$

$$= \frac{wsE_+e^{-j\beta z} - wsE_-e^{+j\beta z}}{\eta s} = \frac{V_+e^{-j\beta z} - V_-e^{+j\beta z}}{\eta s / w}$$

TEM Waves

For a parallel plate waveguide (stripline), the inductance and capacitance per unit length and intrinsic impedance are

$$c = \frac{\varepsilon w}{s} \qquad l = \frac{\mu s}{w}$$

$$Z_o = \sqrt{\frac{l}{c}} = \sqrt{\frac{\mu s/w}{\varepsilon w/s}} = \sqrt{\frac{\mu}{\varepsilon}} \frac{s}{w} = \eta \frac{s}{w}$$

TEM Waves

so the current expression is

$$i(z) = \frac{V_+ e^{-j\beta z} - V_- e^{+j\beta z}}{Z_o}$$

We could have determined this current from the surface current density so we should check to be sure that the two results agree. The total current at any z should be given by

$$i(z) = J_s w = \frac{E_+ e^{-j\beta z} - E_- e^{+j\beta z}}{\eta} w = \frac{V_+ e^{-j\beta z} - V_- e^{+j\beta z}}{Z_o}$$

as before.

TEM Waves

Finally, we can check to see if the charge per unit length (as determined from the boundary condition) gives us the usual capacitance per unit length.

$$q = \rho_s w = \varepsilon w E_+ e^{-j\beta z} + \varepsilon w E_- e^{+j\beta z} = \frac{\varepsilon w}{s}\left(V_+ e^{-j\beta z} + V_- e^{+j\beta z}\right) = cv(z)$$

as expected.

The same analysis can be done for coaxial cables and two-wire lines. The general results are the same.

Standing Waves:
Voltage Standing Wave with Short Circuit Load

Constructive
Interference

Destructive
Interference
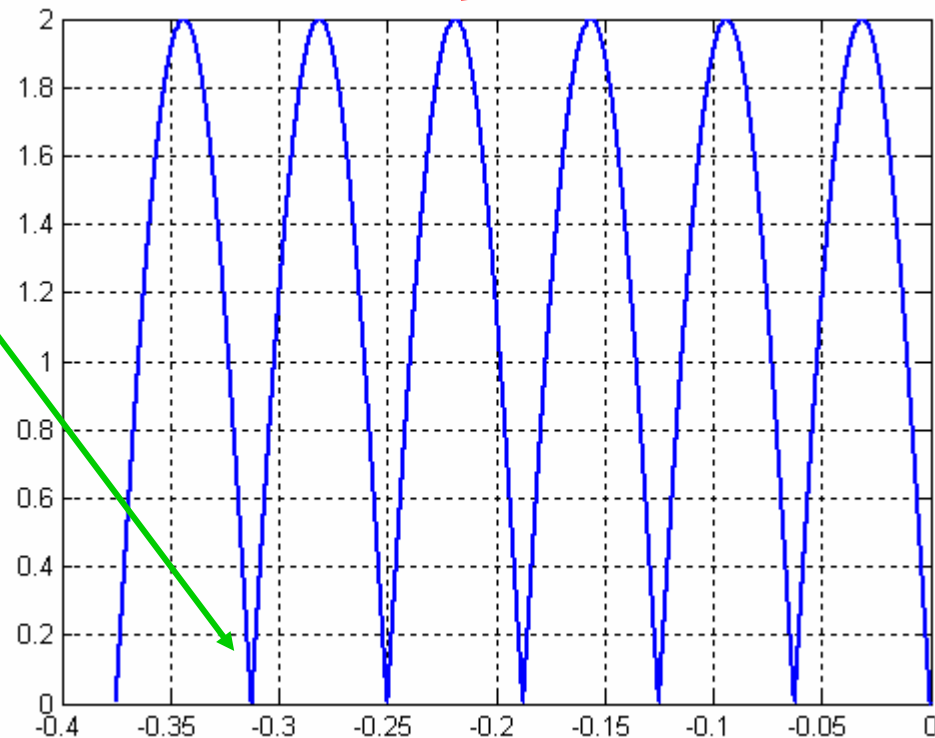
Standing Waves:
Voltage Standing Wave with Open Circuit Load
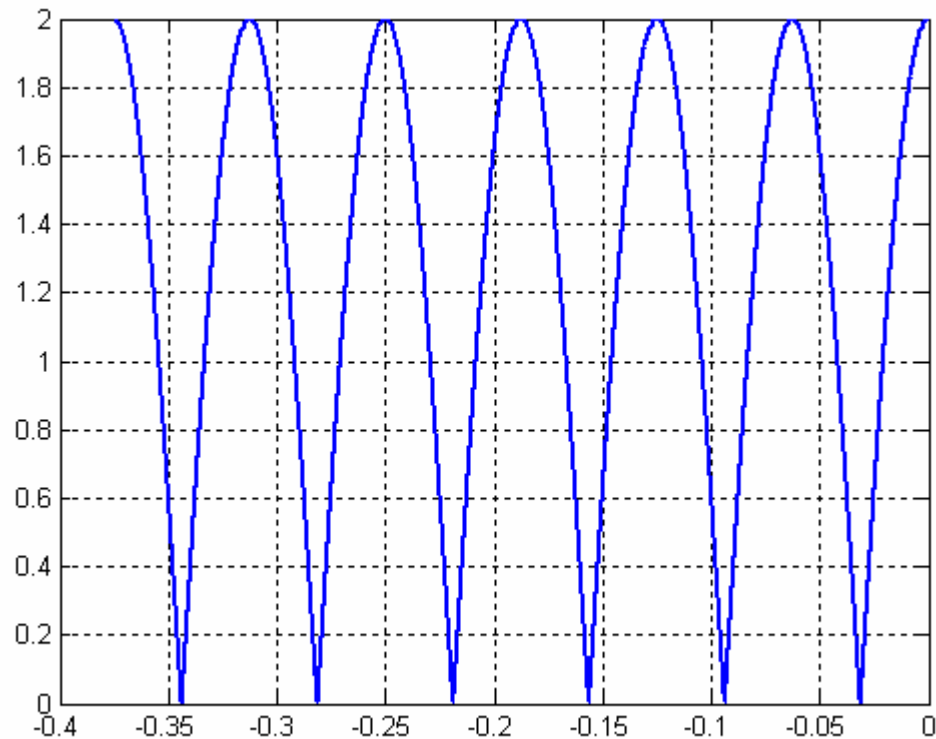
Java Applet of Waves

Standing Wave

- http://www.bessernet.com/Ereflecto/tutorialFrameset.htm
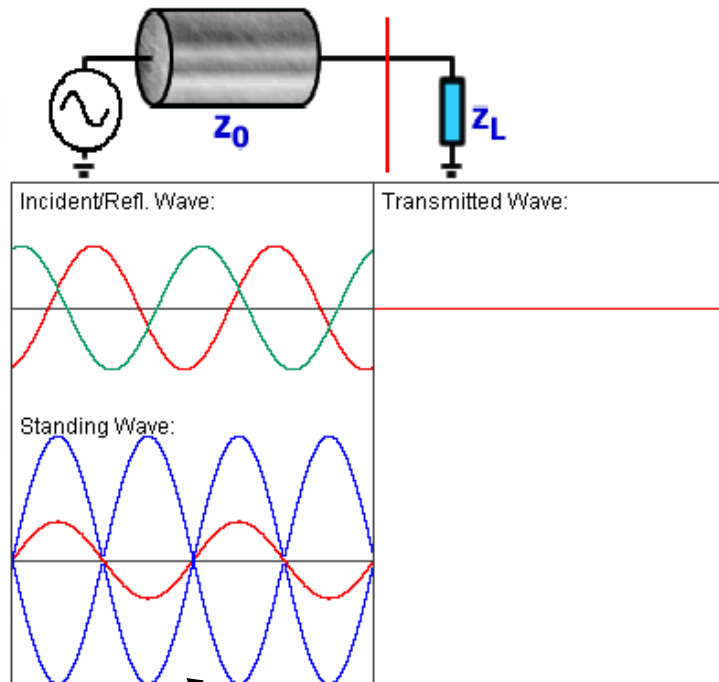
Simple Antennas

- Currents on Wire Antennas
- General Types of Antennas
- The Hertzian Dipole as the Model Antenna
- Other Simple Wire Configurations
- Antenna Parameters & Analysis
- Radiation Patterns
- Yagi & Patch Antennas
- Polarization

Simple Wire Antenna Currents
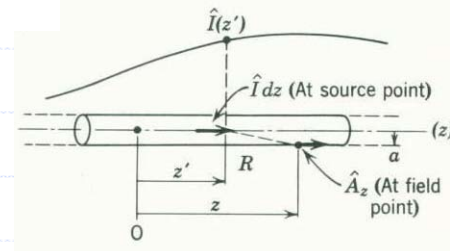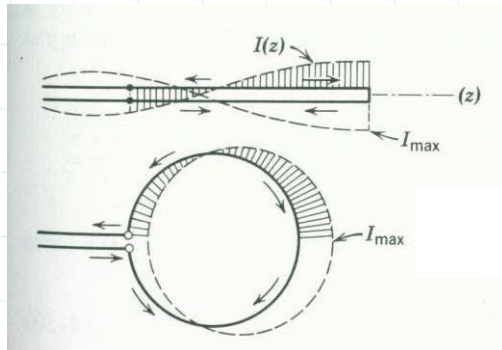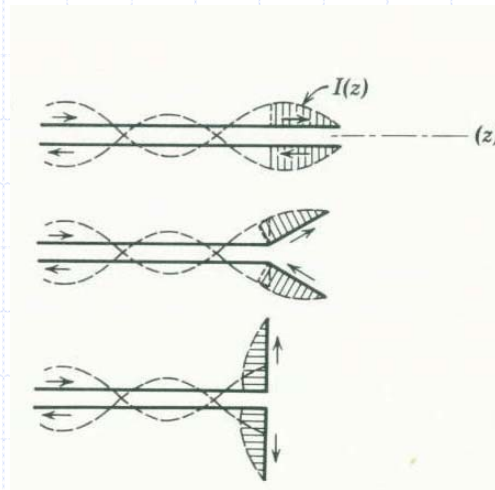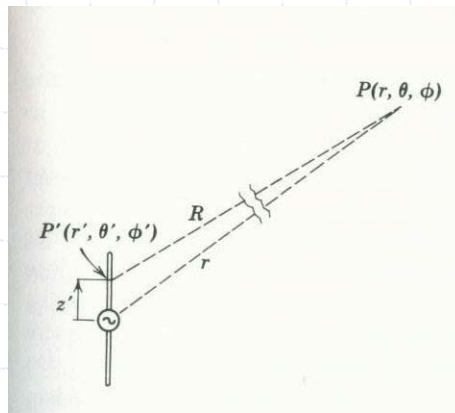
Figure 11-9. Relative to thin-wire antennas and their current distributions. (a) The summing of field contributions at P due to infinitesimal current-elements along an antenna. (b) Linear antenna current standing wave, obtained from a deformation of an open-circuited transmission line. (c) Loop antenna current standing wave, obtained from a deformation of a shorted transmission line. (d) Pertaining to the distribution of a current standing wave along a thin wire, as a function of z.

From CTA Johnk *Engineering Electromagnetic Fields & Waves*

Simple Wire Antenna Currents
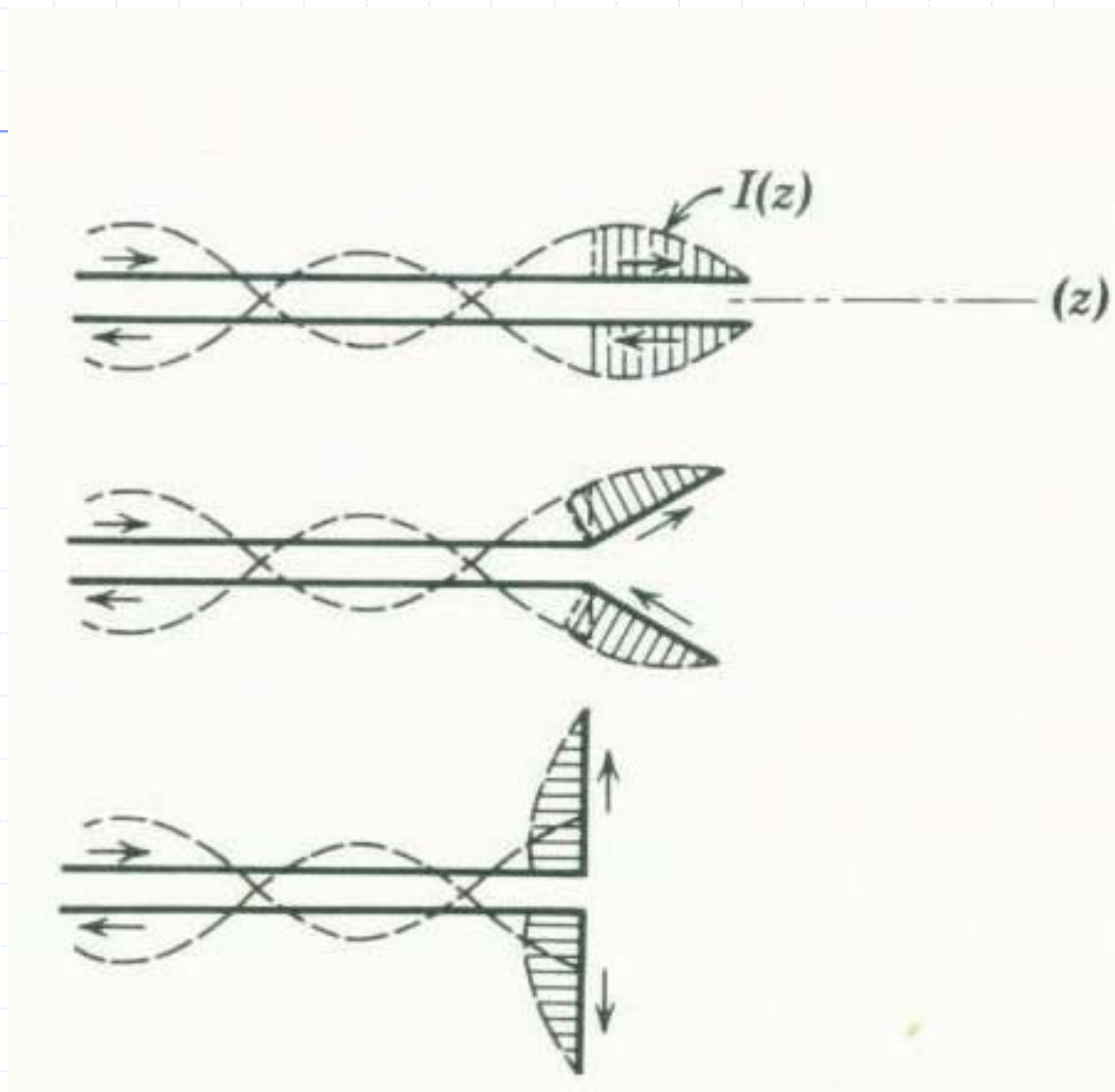
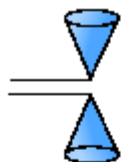# Simple Wire Antenna Currents

Simple Wire Antenna Currents

$P(r, \theta, \phi)$

$P'(r', \theta', \phi')$

R

r

z'

Simple Wire Antenna Currents

$\hat{I}(z')$

$-\hat{I}\,dz$ (At source point)

(z)

a

z' R

z

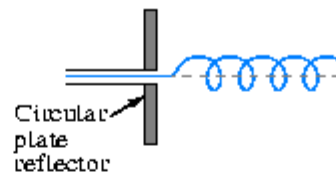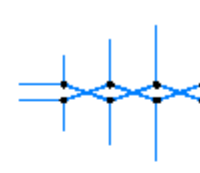$\hat{A}_z$ (At field point)

O
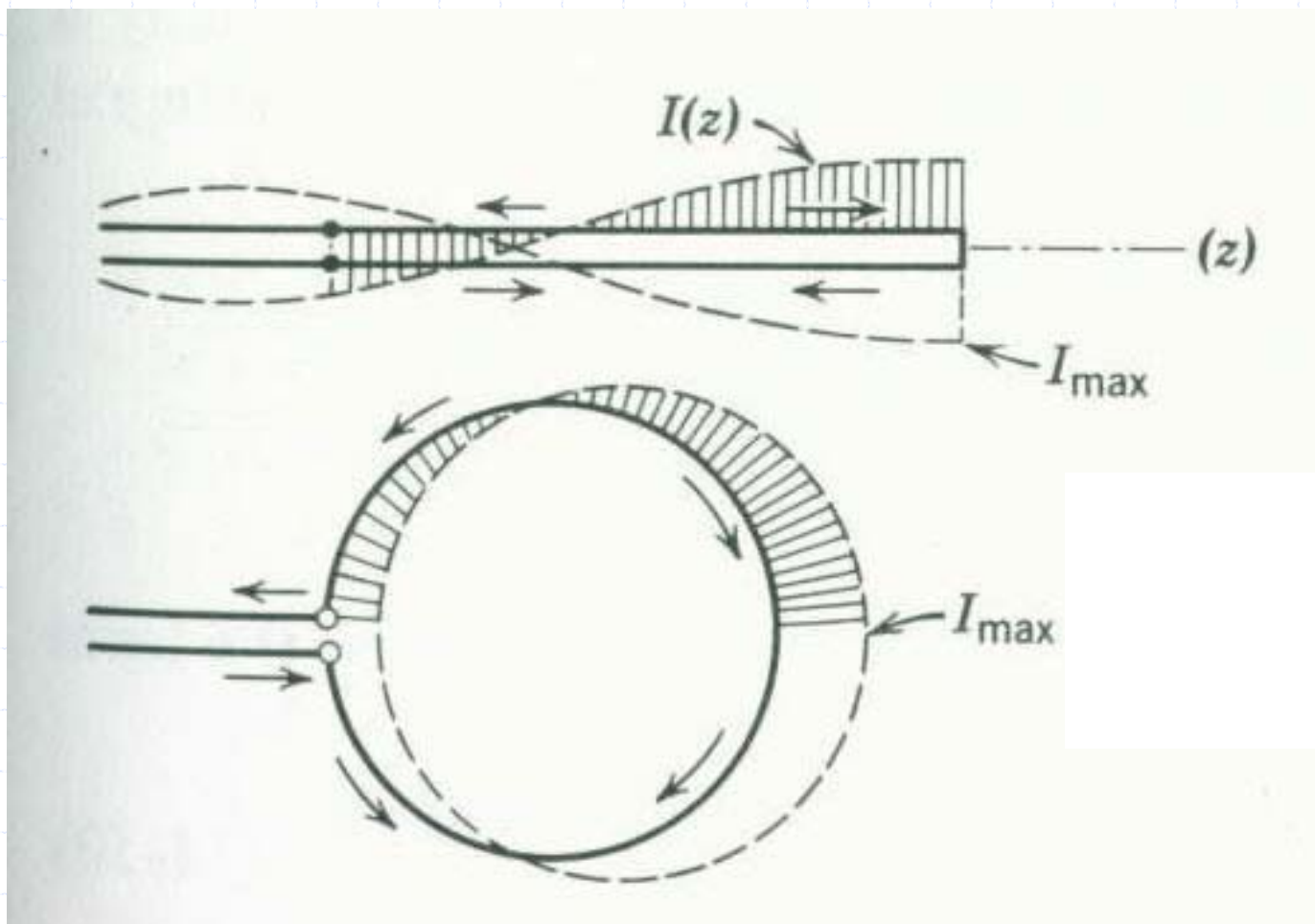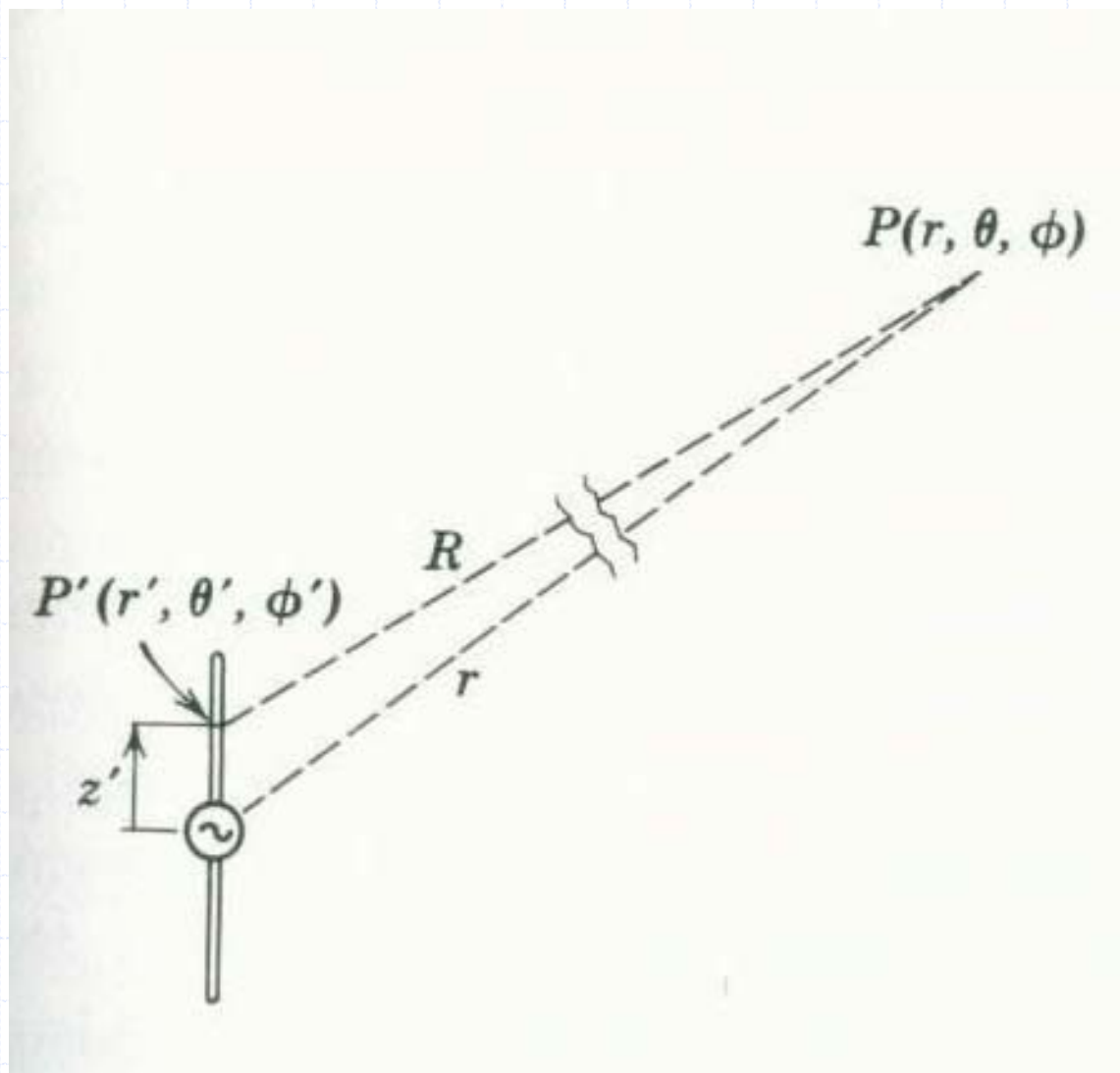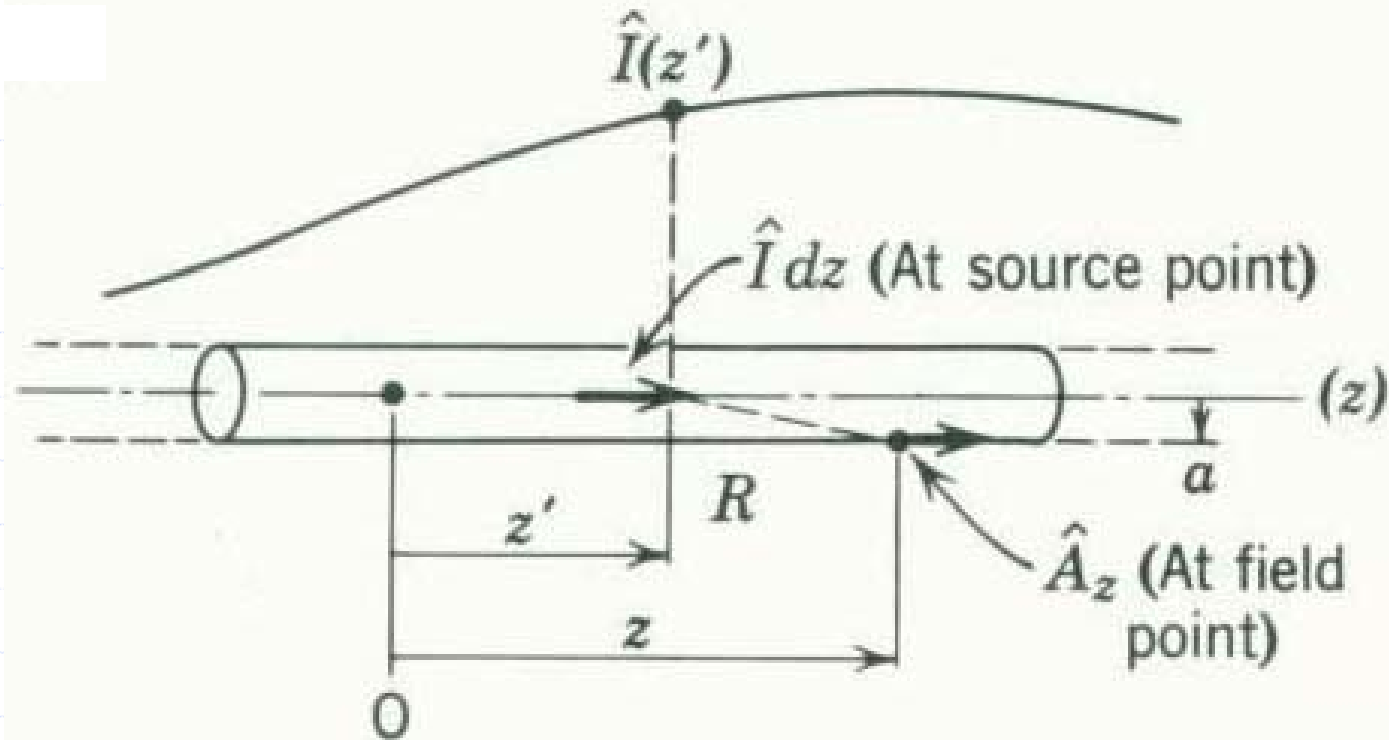
Types of Antennas
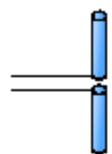
(a) Thin dipole   (b) Biconical dipole   (c) Loop   (d) Helix   (e) Log-periodic
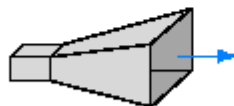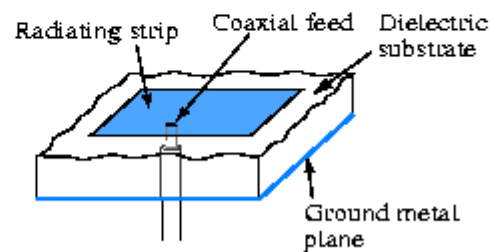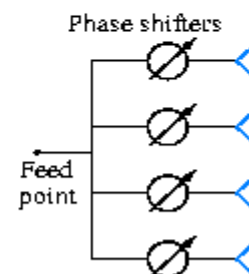
Circular plate reflector
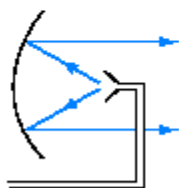
(f) Parabolic dish reflector   (g) Horn   (h) Microstrip   (i) Antenna array

Radiating strip   Coaxial feed   Dielectric substrate
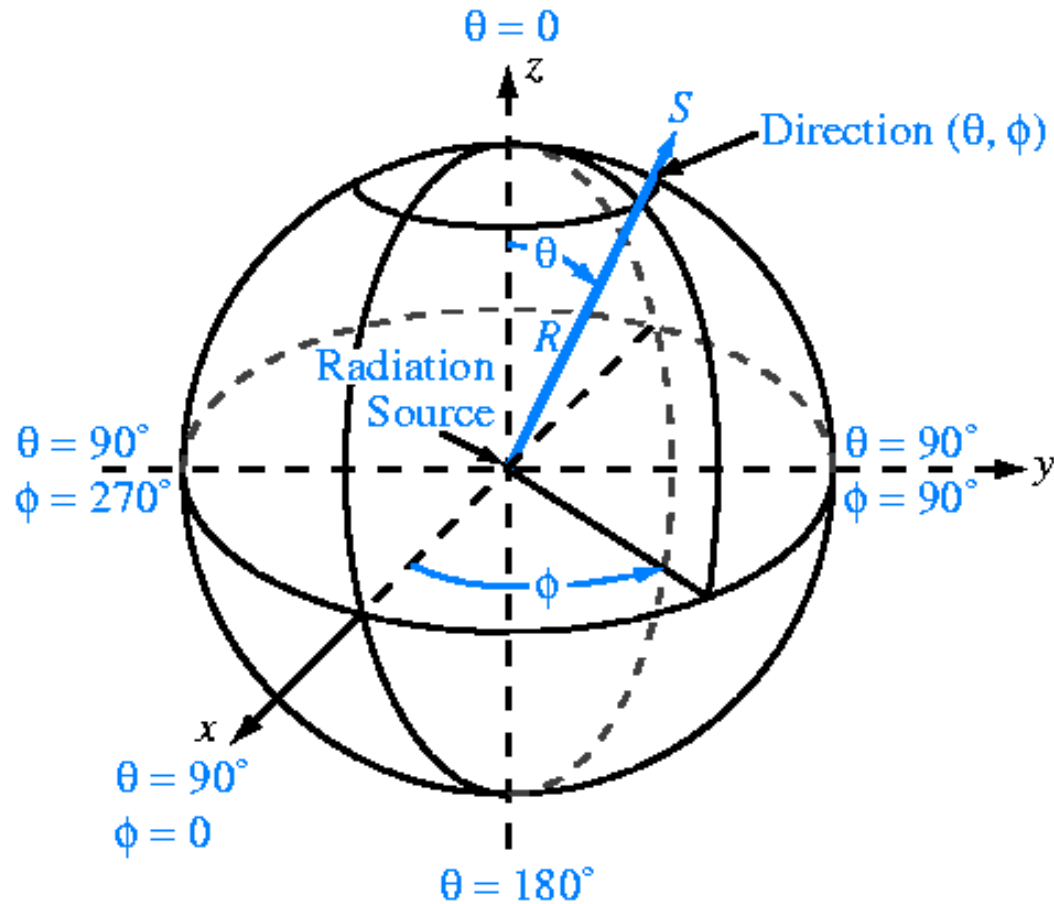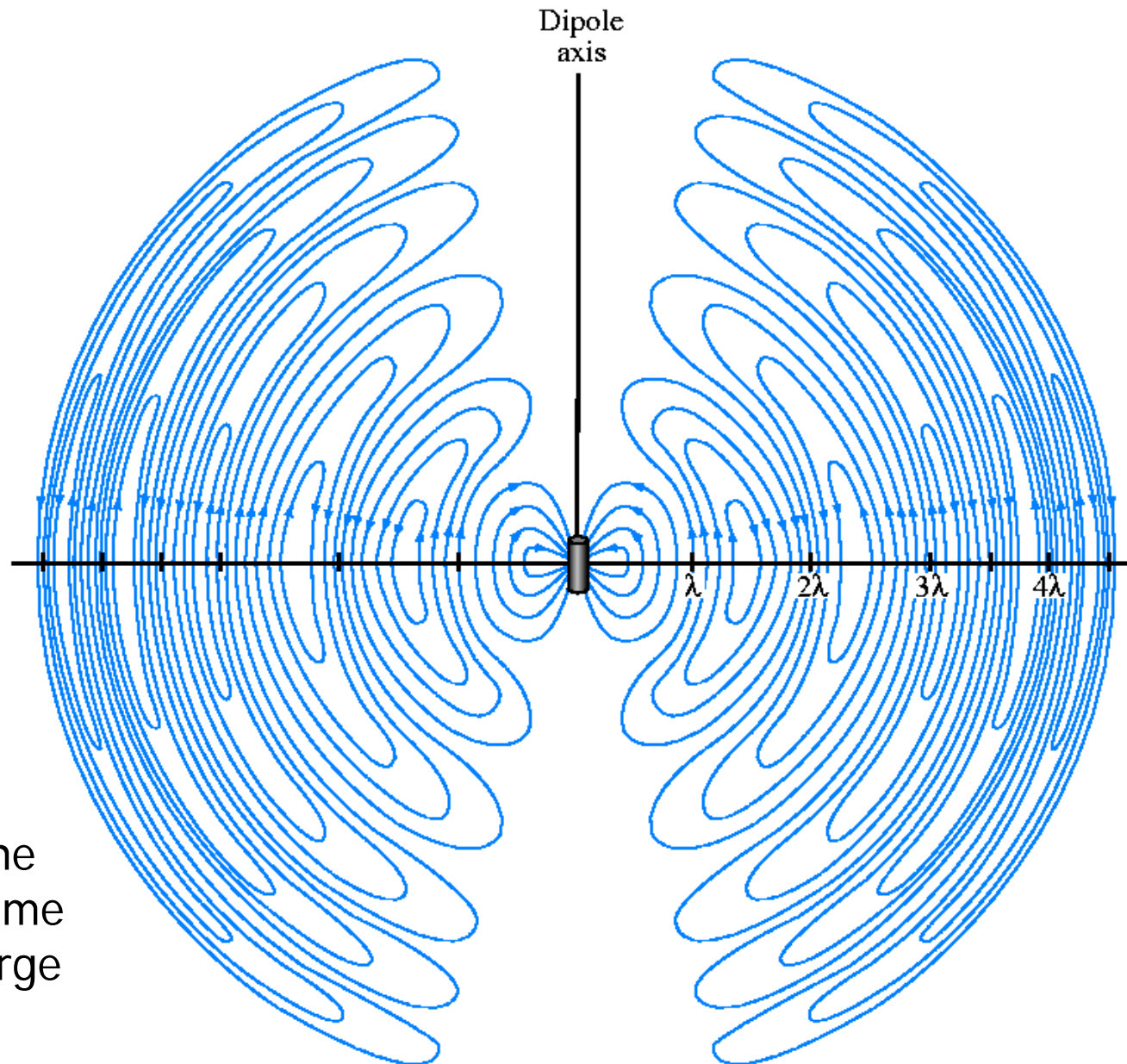
Ground metal plane

Phase shifters

Feed point

Hertzian Dipole

Constant Currents
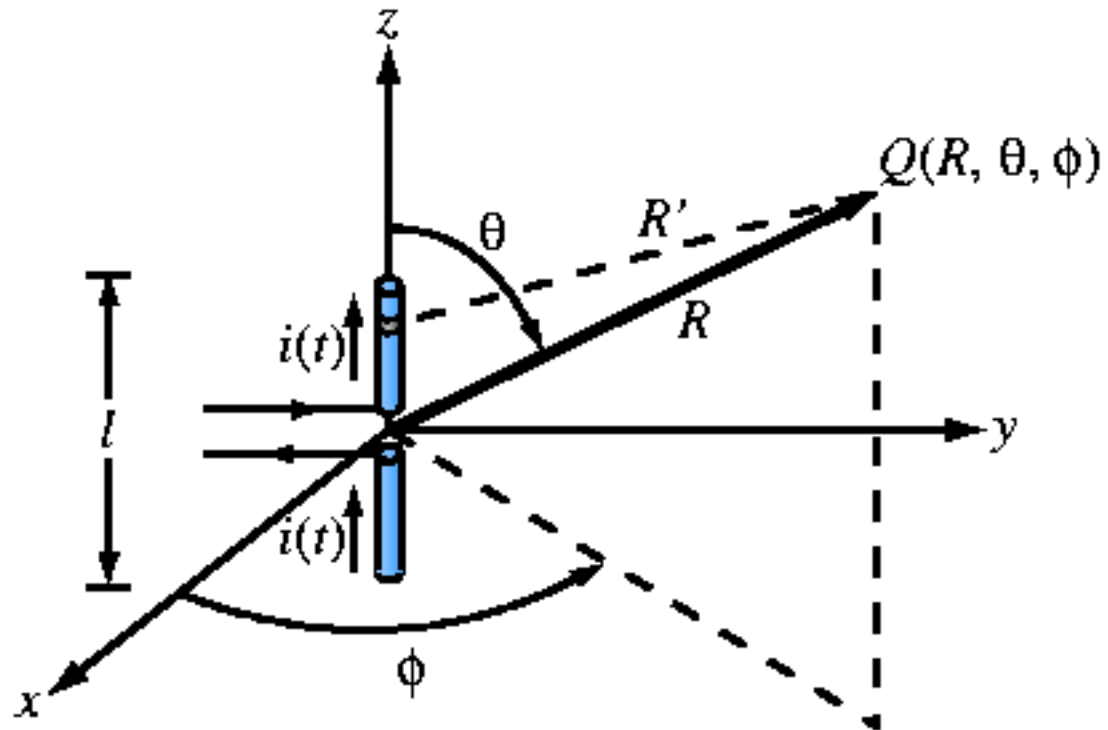
Note the Coordinates
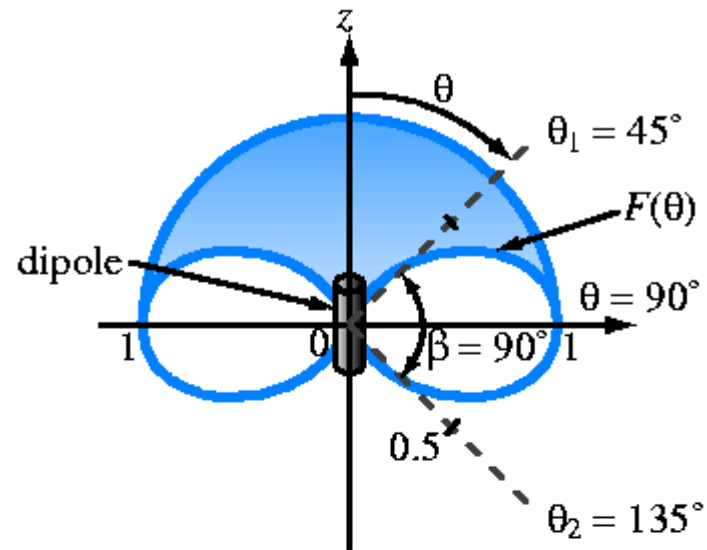
Fields and Waves I

Hertzian Dipole

Note that the waves become planar at large distances
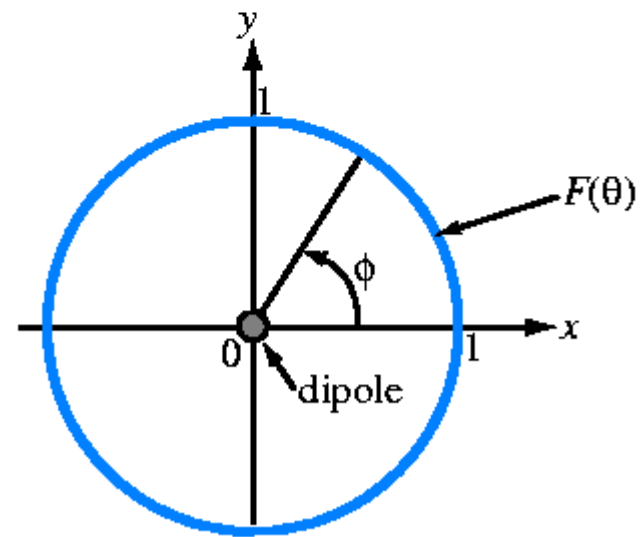
Hertzian Dipole

(a) Elevation pattern

Radiation is primarily to the side
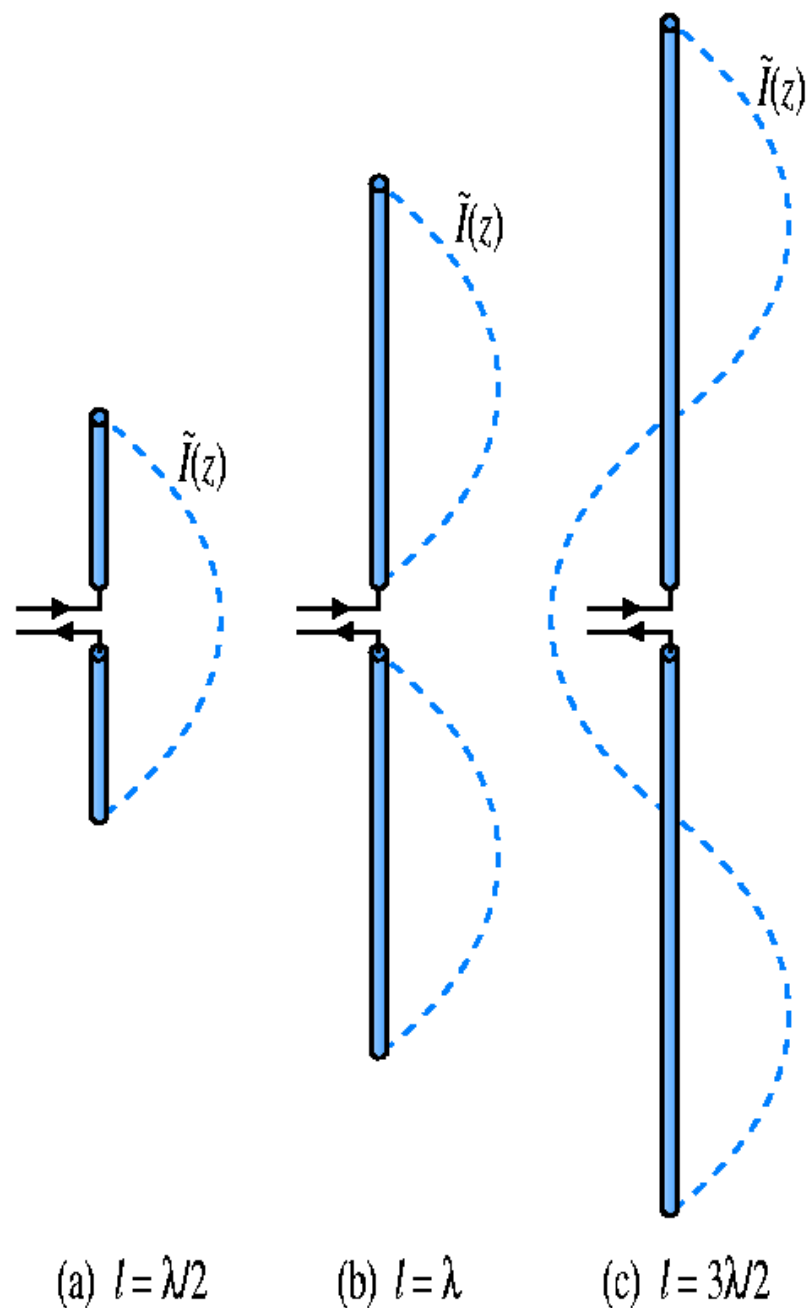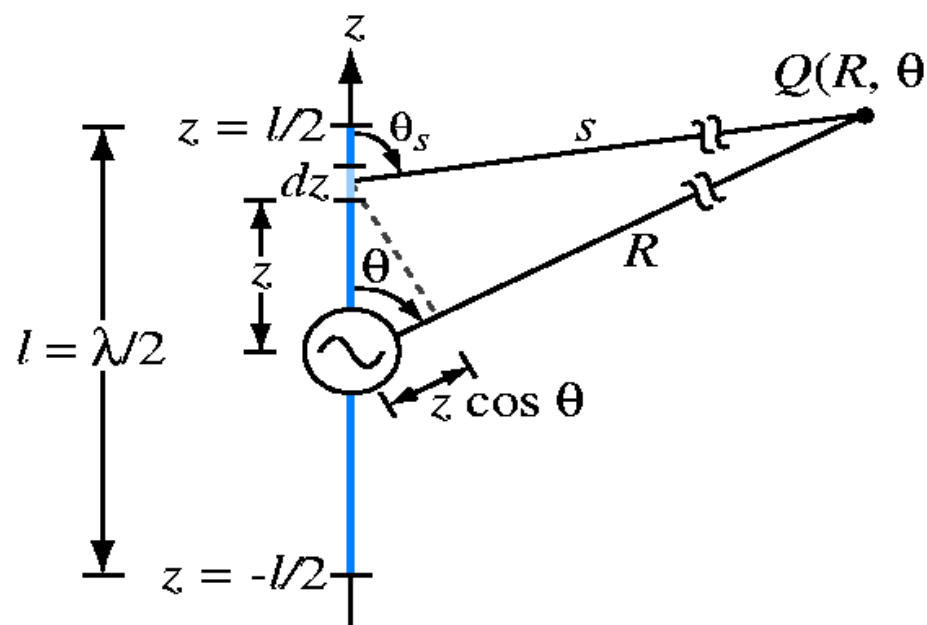
Radiation is isotropic or uniform around the axis of the antenna
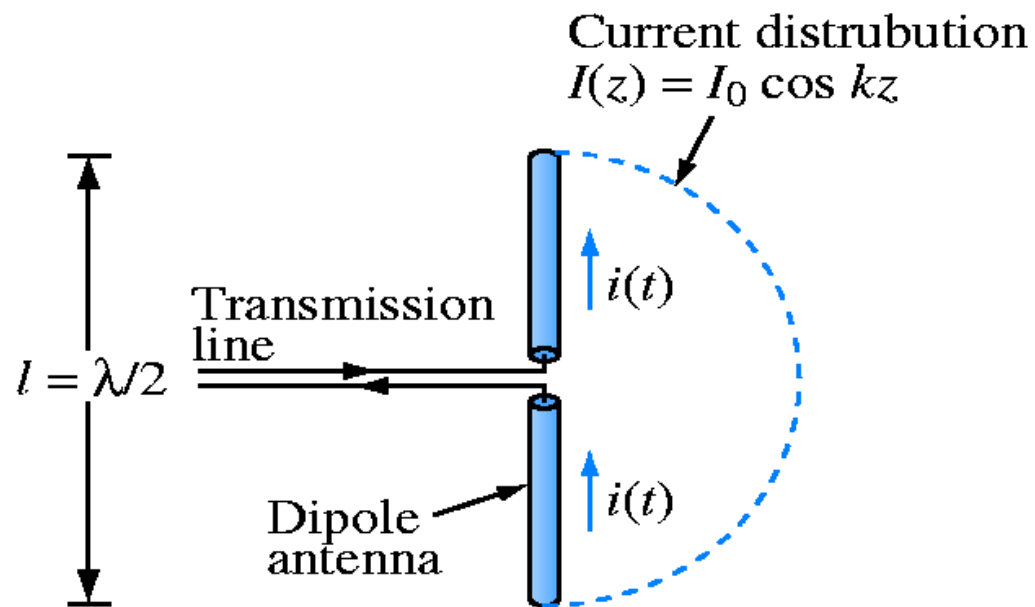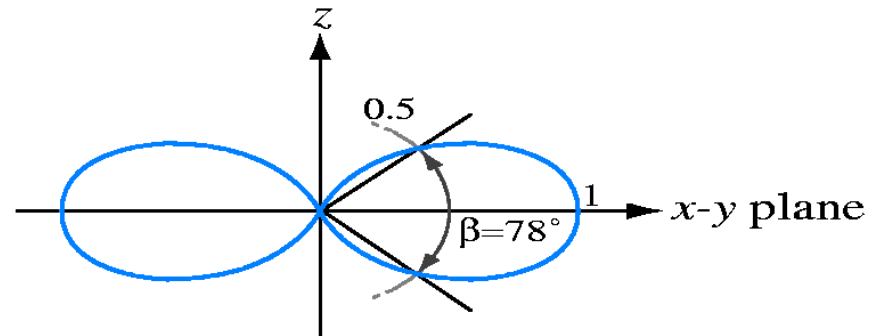
Little or no radiation up or down

(b) Azimuth pattern

Current distrubution
$I(z) = I_0 \cos kz$

Transmission line

$l = \lambda/2$

$i(t)$

$i(t)$

Dipole antenna

z

$Q(R, \theta)$

$z = l/2$ θ_s s

dz

z

θ

R

$l = \lambda/2$

$z \cos \theta$

$z = -l/2$

$\tilde{I}(z)$

$\tilde{I}(z)$

$\tilde{I}(z)$
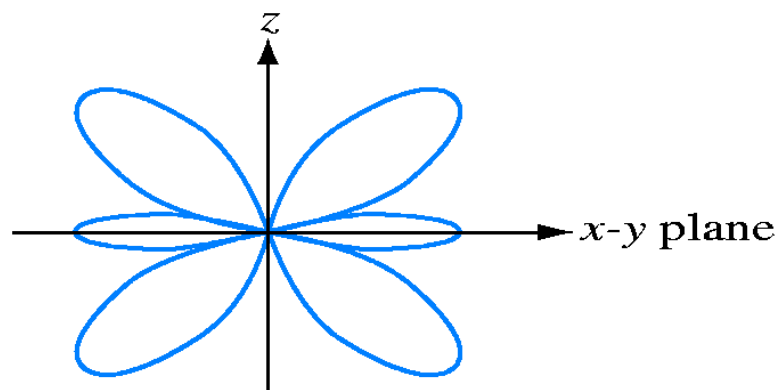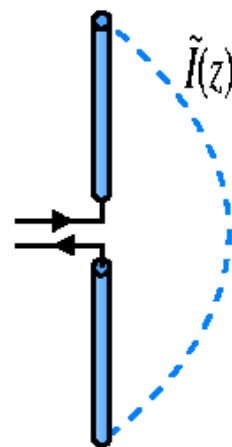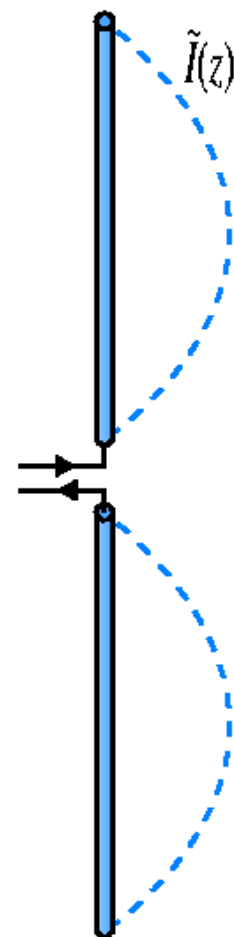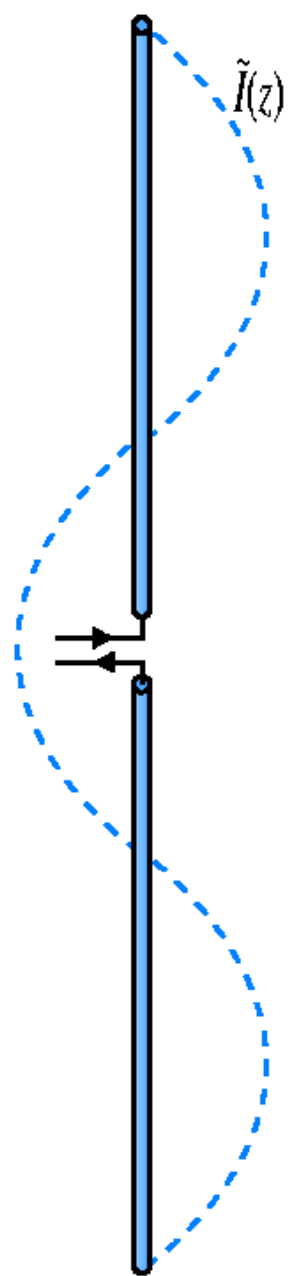
(a) $l = \lambda/2$ (b) $l = \lambda$ (c) $l = 3\lambda/2$

(a) $l = \lambda/2$
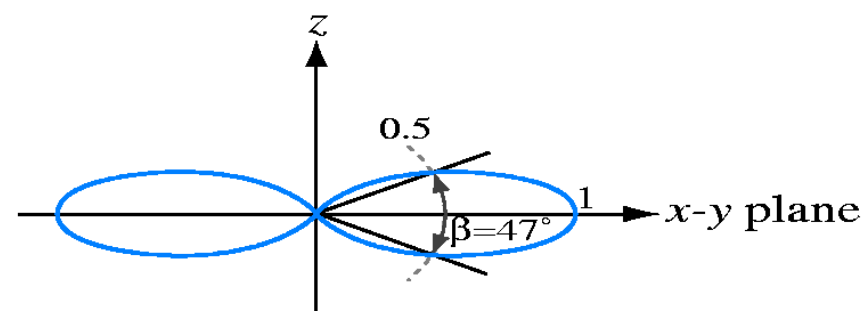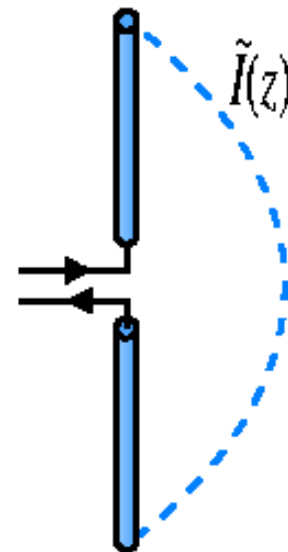
(b) $l = \lambda$

(c) $l = 3\lambda/2$

(a) $l = \lambda/2$

(b) $l = \lambda$

(c) $l = 3\lambda/2$

Short Dipole

Electric field lines of radiated wave

Antenna

Transmission line

Generator   Guided EM wave

Transition region

Source

Transmitting antenna

Spherical wave

R

Receiving antenna

Plane-wave approximation

A_t

A_r

Wave launched into free space P_t

P_{rad}

R

P_{int}

P_{rec}

(a) Transmission mode

Antenna

Transmission line

Rec

Detector or receiver   Guided EM wave

Transition region

Incident wave

Transmitting antenna

Receiving antenna

x_a

$E_a(x_a, y_a)$

Q

R

θ

z

y_a

(b) Reception mode

36

Aperture Antennas

Figure 9-24

(a) Pencil beam

(b) Fan beam

Antenna Parameters

- Calculate the Electric and Magnetic Fields from the Antenna Currents – usually requires the use of potentials

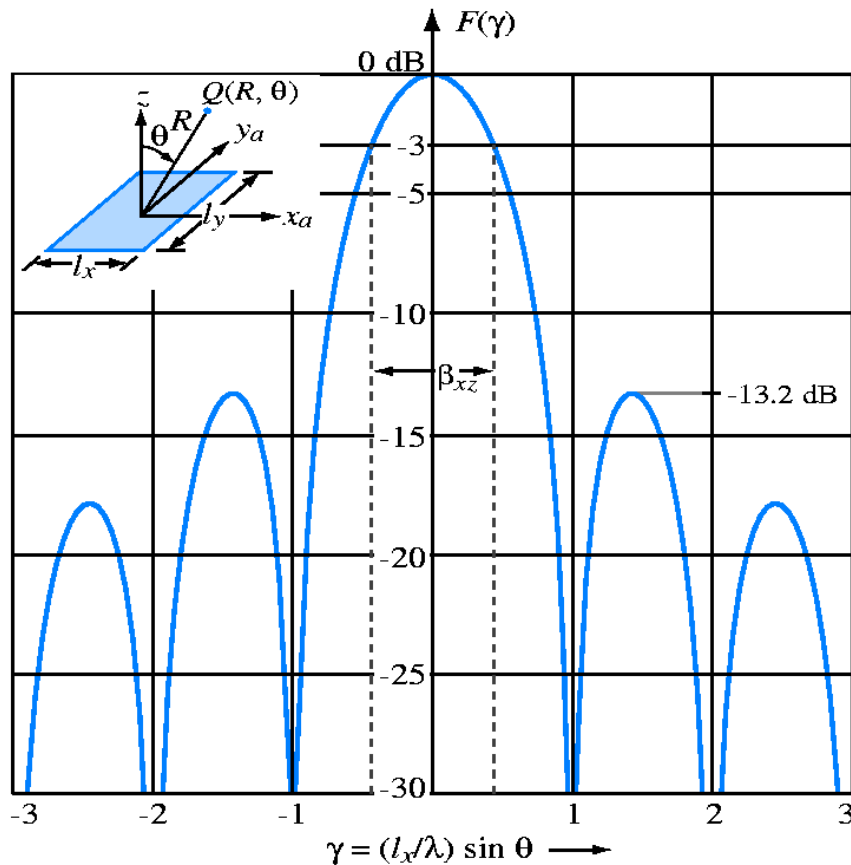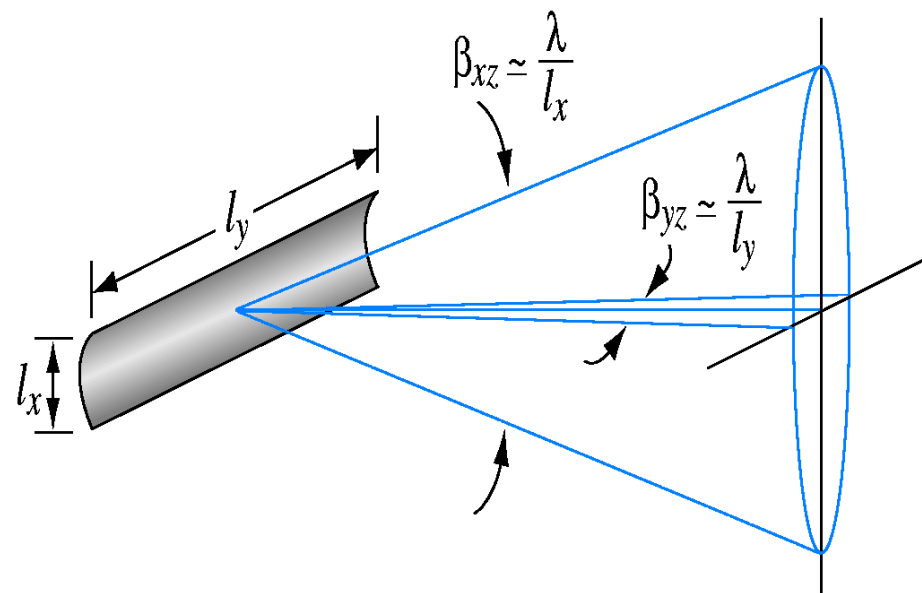- Far Fields are Products of terms like the following – (depends on current and inversely on position), spherical wave, field pattern $F(\theta)$

- Determine the Poynting Vector – Power Density is product of E and H – average goes inversely with position squared and with $F^2(\theta)$

- Gain is the ratio of power density to isotropic value

- Radiation Resistance is twice the average total power divided by the current squared

Antenna Analysis

Hertzian Dipole
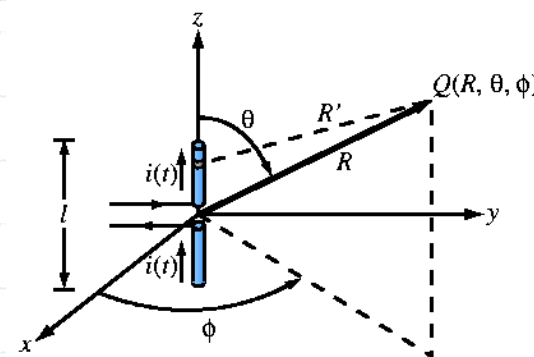
$$\vec{A} = \left(\frac{\mu_0 I_0 \delta_l}{4\pi r} \right) \cos(\omega t - \beta r)\vec{i}_z.$$
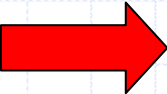
$$A_r = \left(\frac{\mu_0 I_0 \delta_l}{4\pi r} \right) \cos(\omega t - \beta r) \cos(\theta)$$

$$A_\theta = -\left(\frac{\mu_0 I_0 \delta_l}{4\pi r} \right) \cos(\omega t - \beta r) \sin(\theta)$$

Antenna Analysis

$$\vec{H} \quad = \quad \frac{\vec{B}}{\mu_0} = \frac{1}{\mu_0}\vec{\nabla} \times \vec{A}$$

$$= \quad \frac{1}{\mu_0 r}\left[\frac{\partial}{\partial r}(rA_\theta) - \frac{\partial A_r}{\partial \theta}\right] \cdot \vec{i}_\phi$$

$$= \quad \frac{I_0\delta_l \sin(\theta)}{4\pi}\left[\frac{cos(\omega t - \beta r)}{r^2} - \frac{\beta\sin(\omega t - \beta r)}{r}\right]\vec{i}_\phi$$

or

$$H_\phi \quad = \quad \frac{1}{\mu_0 r}\left[\frac{\partial}{\partial r}(rA_\theta) - \frac{\partial A_r}{\partial \theta}\right]$$

$$= \quad \frac{I_0\delta_l \sin(\theta)}{4\pi}\left[\frac{cos(\omega t - \beta r)}{r^2} - \frac{\beta\sin(\omega t - \beta r)}{r}\right]$$

Antenna Analysis

$$\frac{\partial \vec{E}}{\partial t} = \frac{1}{\epsilon_0} \vec{\nabla} \times \vec{H}$$

$$= \frac{1}{\epsilon_0 r^2 \sin(\theta)} \frac{\partial}{\partial \theta} \left(r \sin(\theta) H_\phi \right) \vec{i}_r - \frac{1}{\epsilon_0 r \sin(\theta)} \frac{\partial}{\partial r} \left(r \sin(\theta) H_\phi \right) \vec{i}_\theta$$

Taking the derivatives of H_ϕ and integrating over time yields

$$\vec{E} = \frac{2 I_0 \delta_l \cos(\theta)}{4 \pi \epsilon_0 \omega} \left[\frac{\sin(\omega t - \beta r)}{r^3} + \frac{\beta \cos(\omega t - \beta r)}{r^2} \right] \vec{i}_r$$

$$+ \frac{I_0 \delta_l \sin(\theta)}{4 \pi \epsilon_0 \omega} \left[\frac{\sin(\omega t - \beta r)}{r^3} + \frac{\beta \cos(\omega t - \beta r)}{r^2} - \frac{\beta^2 \sin(\omega t - \beta r)}{r} \right] \vec{i}_\theta$$

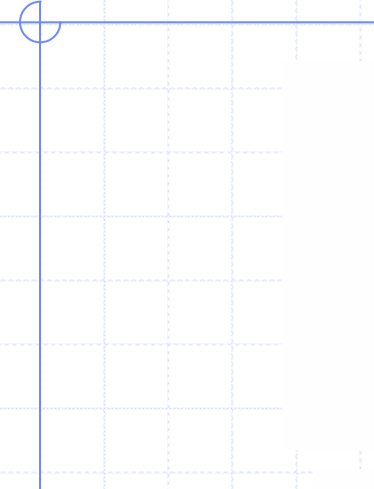# Antenna Analysis

- **Keep Only The Largest Terms in the Far Field**

$$\vec{H}(r \gg \lambda/2\pi) = -\left[\frac{I_0 \delta_l \beta}{4\pi}\right]\left[\frac{\sin(\theta)}{r}\right]\sin(\omega t - \beta r)\vec{i}_\phi$$

and

$$\vec{E}(r \gg \lambda/2\pi) = -\left[\frac{I_0 \delta_l \beta^2}{4\pi\epsilon_0\omega}\right]\left[\frac{\sin(\theta)}{r}\right]\sin(\omega t - \beta r)\vec{i}_\theta$$

$$= -\left[\frac{\eta I_0 \delta_l \beta}{4\pi}\right]\left[\frac{\sin(\theta)}{r}\right]\sin(\omega t - \beta r)\vec{i}_\theta$$

Antenna Analysis

$$F^2(\theta)$$

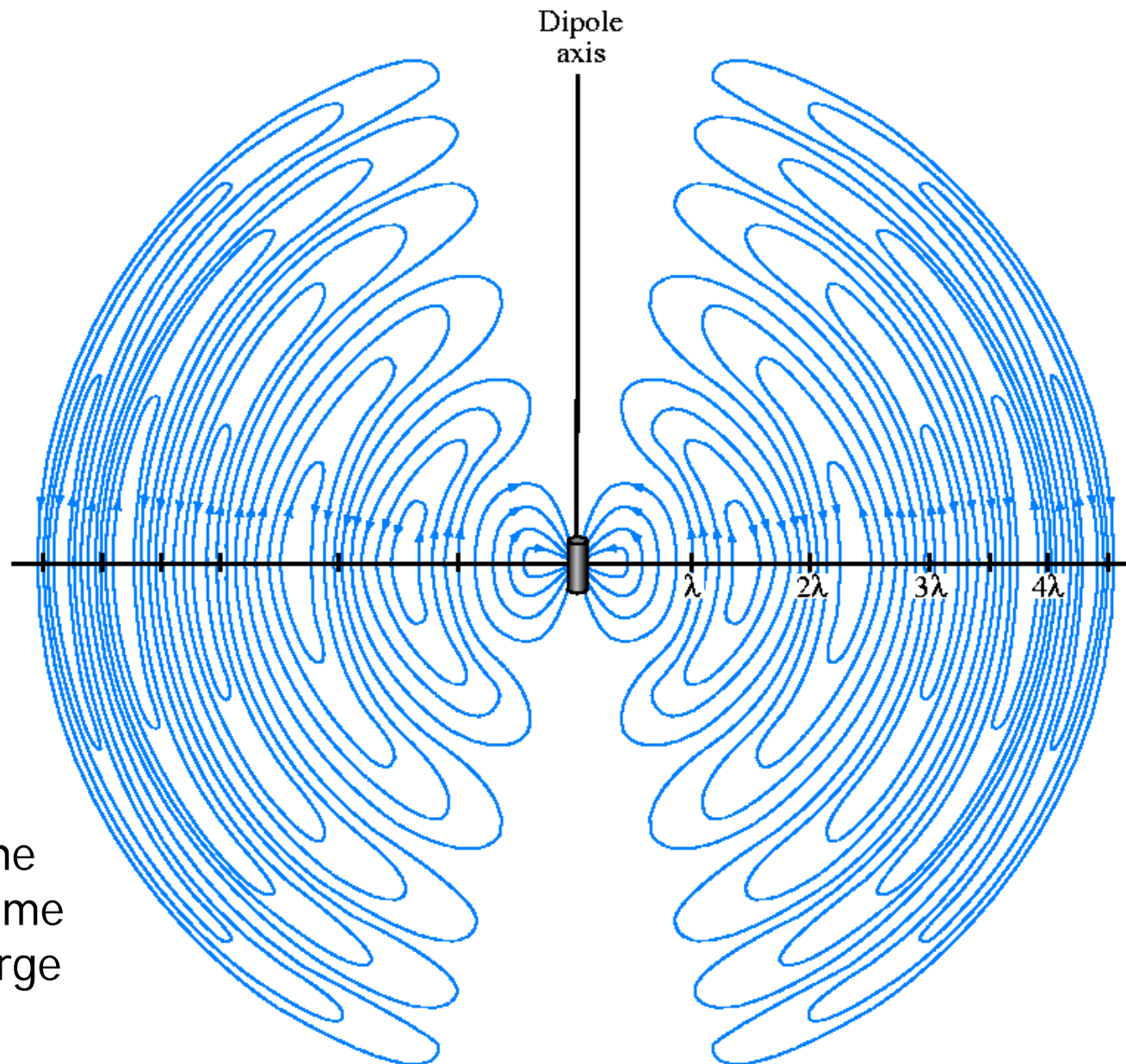$$\vec{P} = \vec{E} \times \vec{H}$$

$$= E_\theta \vec{i}_\theta \times H_\phi \vec{i}_\phi$$

$$= \left[\frac{\eta \beta^2 I_0^2 (\delta_l)^2 \sin^2(\theta)}{16\pi^2 r^2} \right] \sin^2(\omega t - \beta r) \vec{i}_r$$

$$P_{rad} = \int_{\theta=0}^{\pi} \int_{\phi=0}^{2\pi} \left[(\vec{P} \cdot \vec{i}_r \right] r^2 \sin(\theta) \ d\theta d\phi$$

$$= \frac{\eta \beta^2 I_0^2 (\delta_l)^2}{6\pi} \sin^2(\omega t - \beta r)$$

$$= \frac{2\pi \eta I_0^2}{3} \left(\frac{\delta_l}{\lambda} \right)^2 \sin^2(\omega t - \beta r)$$

Antenna Analysis

$$
\begin{aligned}
< P_{rad} > \quad &= \quad \frac{\pi \eta I_0^2}{3} \left(\frac{\delta_l}{\lambda} \right)^2 < \sin^2(\omega t - \beta r) > \\
&= \quad \frac{I_0^2}{2} \left[\frac{2\pi \eta}{3} \left(\frac{\delta_l}{\lambda} \right)^2 \right]
\end{aligned}
$$

$$
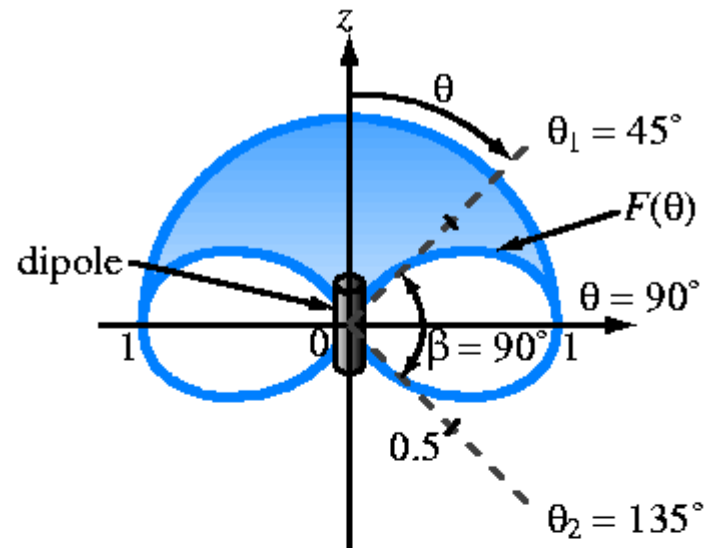R_{rad} = \frac{2\pi \eta}{3} \left(\frac{\delta_l}{\lambda} \right)^2
$$

Dipole axis

λ 2λ 3λ 4λ

Note that the waves become planar at large distances
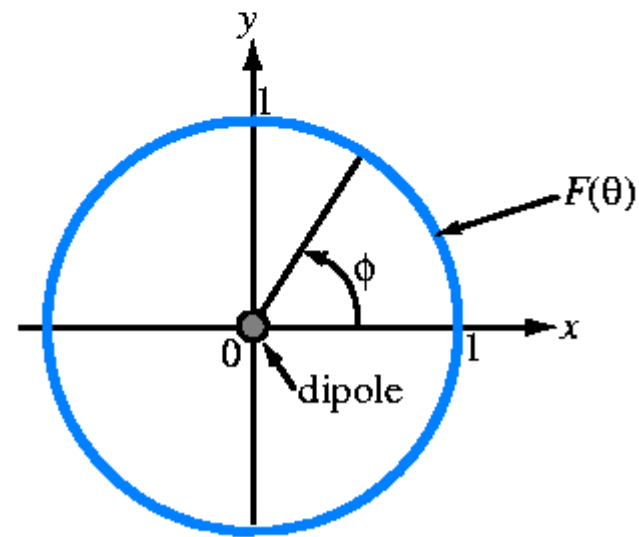
Hertzian Dipole

(a) Elevation pattern

Radiation is primarily to the side

Radiation is isotropic or uniform around the axis of the antenna

Little or no radiation up or down

(b) Azimuth pattern

Half Wave Dipole

$$E_\theta = -\left[\frac{\eta I_0}{2\pi r}\right]\left[\frac{\cos[(\pi/2)\cos(\theta)]}{\sin(\theta)}\right]\sin(\omega t - \beta r)$$

$$H_\phi = -\left[\frac{I_0}{2\pi r}\right]\left[\frac{\cos[(\pi/2)\cos(\theta)]}{\sin(\theta)}\right]\sin(\omega t - \beta r)$$

$$\vec{P} = \vec{E} \times \vec{H}$$

$$= \left[\frac{\eta I_0^2}{4\pi^2 r^2}\right]\left[\frac{\cos^2[(\pi/2)\cos(\theta)]}{\sin^2(\theta)}\right]\sin^2(\omega t - \beta r)$$
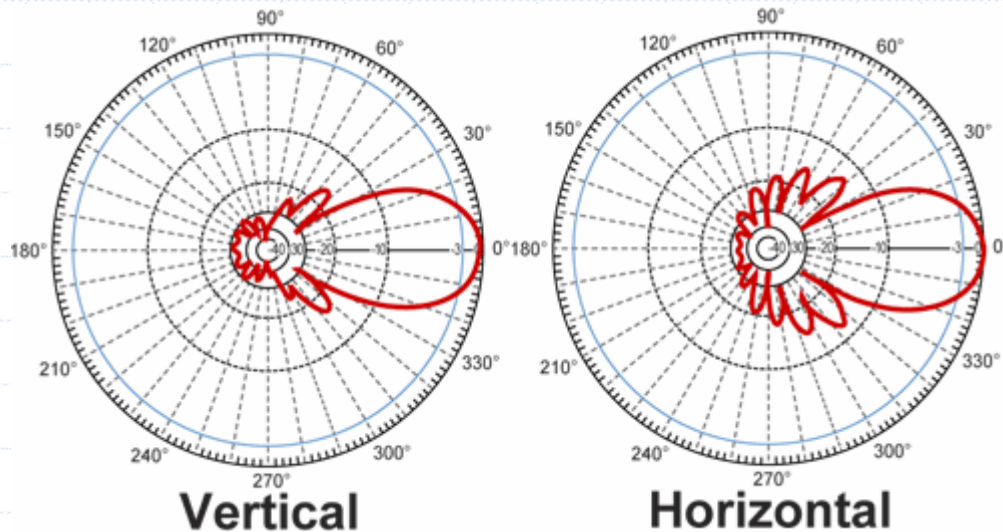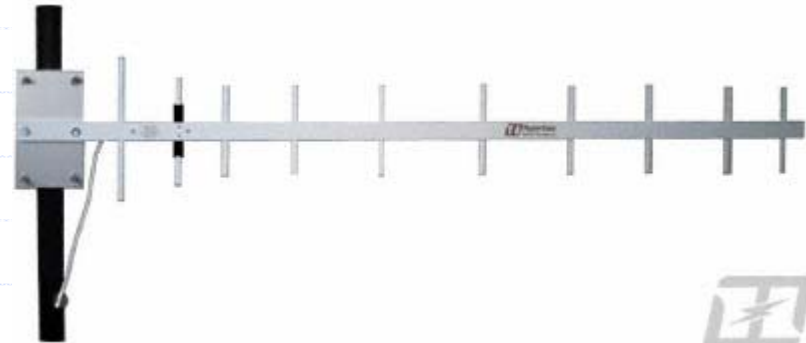
$$P_{rad} = \left[\frac{0.609\eta I_0^2}{\pi}\right]\sin^2(\omega t - \beta r)$$

$$<P_{rad}> = \frac{1}{2}\cdot I_0^2 \cdot \left[\frac{0.609\eta}{\pi}\right]$$
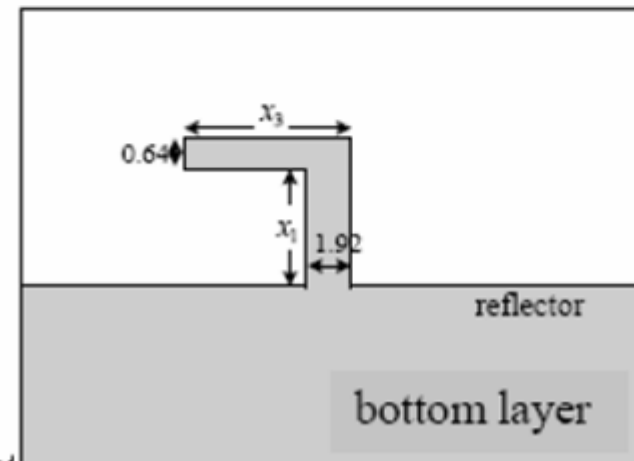
$$R_{rad} = \frac{0.609\eta}{\pi}\ \text{ohms}$$

$$F^2(\theta)$$
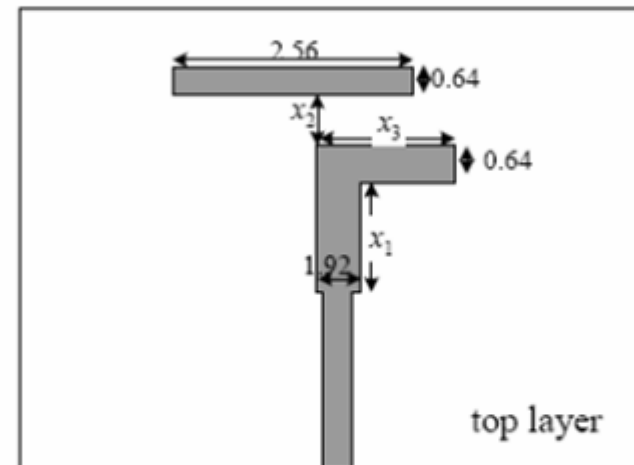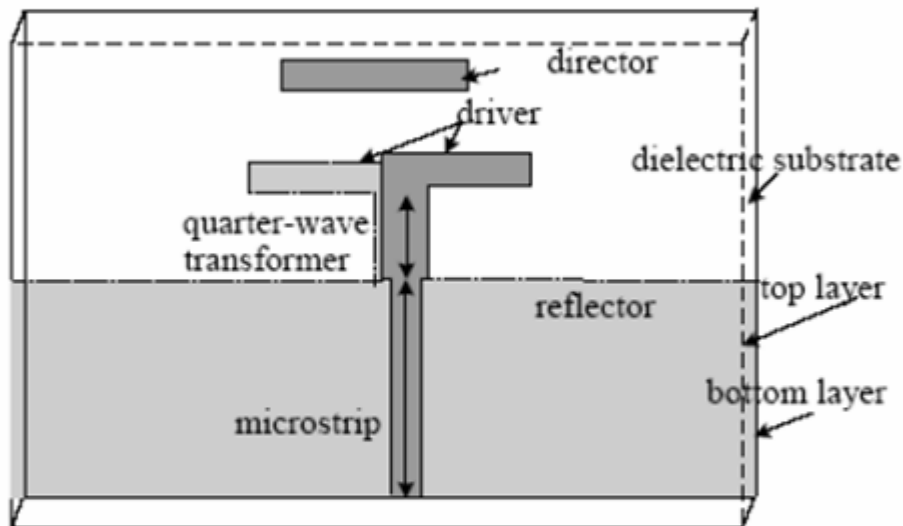
Radiation Patterns

Vertical   Horizontal

http://www.hyperlinktech.com/web/hg914y.php

Example

double-layer printed Yagi antenna

director

driver

dielectric substrate

quarter-wave transformer

reflector

top layer

bottom layer

microstrip

2.56

0.64

x_2

x_3

0.64

x_1

1.92

top layer

x_3

0.64

x_1

1.92

reflector

bottom layer

Note: no galvanic contact with the director

Property of R Struzak

Power pattern vs. Field pattern

Antenna
under test
or reference
antenna

Auxiliary
antenna

← Large distance →

Power or
field-strength meter

Generator

Turntable
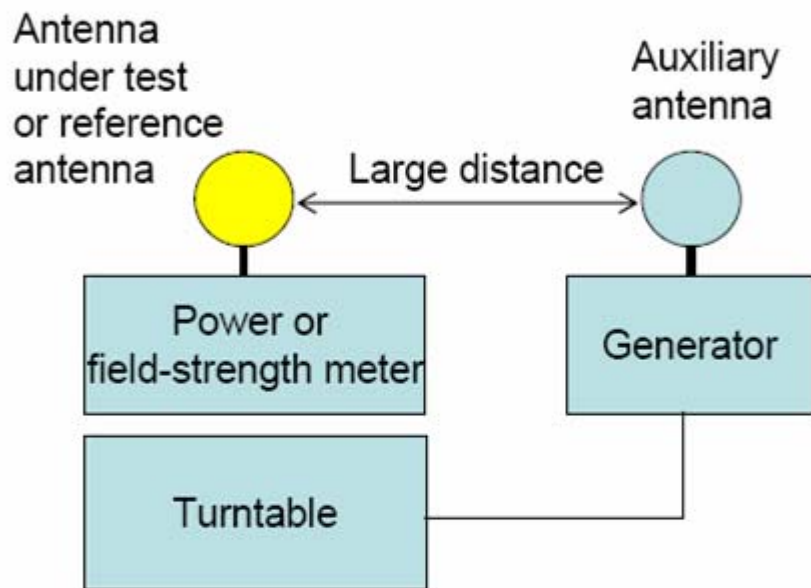
- The power pattern and the field patterns are inter-related:

$$P(\theta, \varphi) = (1/\eta)*|E(\theta, \varphi)|^2 = \eta*|H(\theta, \varphi)|^2$$

   P = power

   E = electrical field component vector

   H = magnetic field component vector

   η = 377 ohm (free-space, plane wave impedance)

- The *power pattern* is the measured (calculated) and plotted received power: $|P(\theta, \varphi)|$ at a constant (large) distance from the antenna

- The *amplitude field pattern* is the measured (calculated) and plotted electric (magnetic) field intensity, $|E(\theta, \varphi)|$ or $|H(\theta, \varphi)|$ at a constant (large) distance from the antenna

Property of R Struzak

Normalized pattern

- Usually, the pattern describes the *normalized* field (power) values with respect to the maximum value.

  – Note: The power pattern and the amplitude field pattern are the same when computed and when plotted in dB.
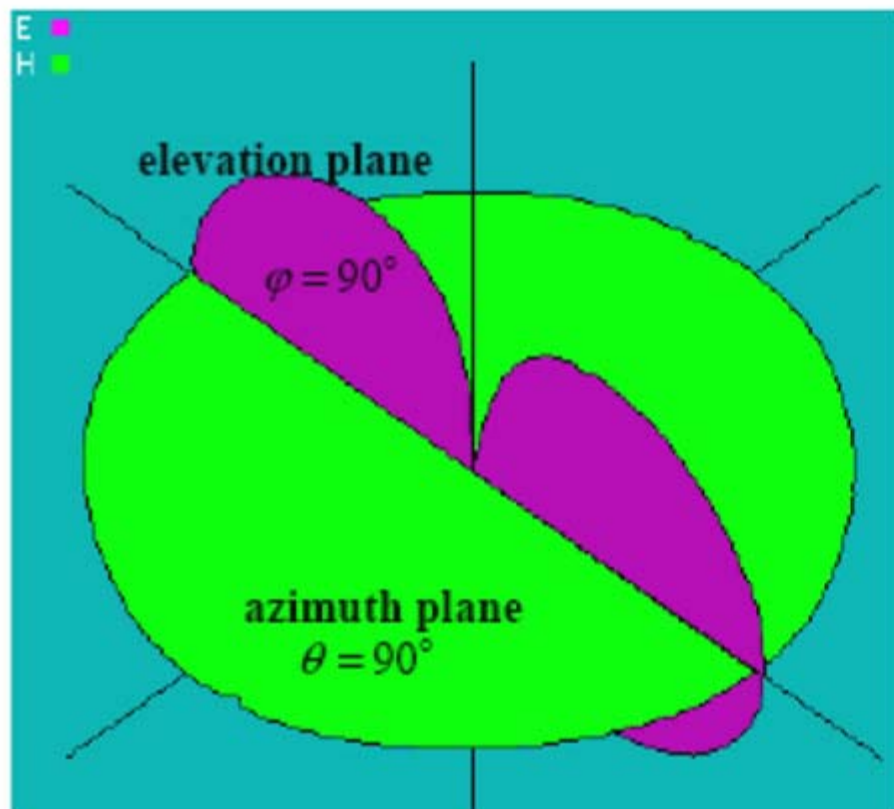
3-D pattern
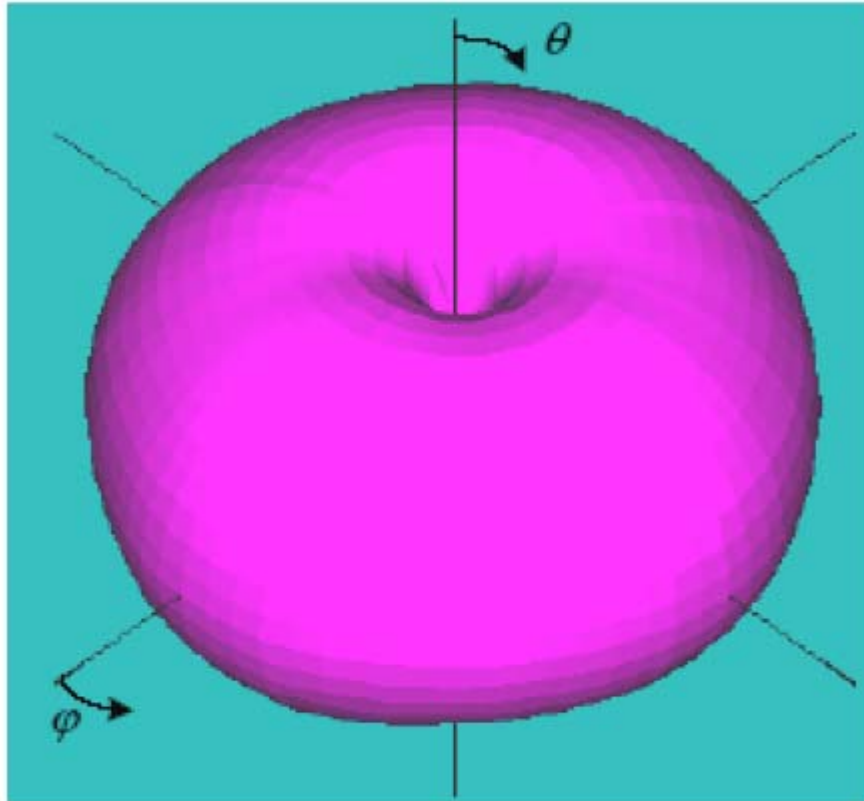
3-D pattern

- Antenna radiation pattern is 3-dimensional

- The 3-D plot of antenna pattern assumes both angles θ and φ varying, which is difficult to produce and to interpret
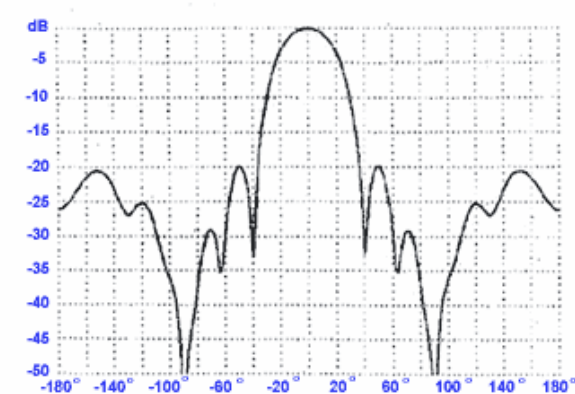
2-D pattern

Two 2-D patterns

- Usually the antenna pattern is presented as a 2-D plot, with only one of the direction angles, θ or φ varies
- It is an intersection of the 3-D one with a given plane
  - usually it is a θ = *const* plane or a φ= *const* plane that contains the pattern's maximum

Source: NK Nikolova

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Principal patterns

- Principal patterns are the 2-D patterns of linearly polarized antennas, measured in 2 planes

  1. the **E-plane:** a plane parallel to the E vector and containing the direction of maximum radiation, and

  2. the **H-plane:** a plane parallel to the H vector, orthogonal to the E-plane, and containing the direction of maximum radiation

Source: NK Nikolova

Property of R Struzak

31

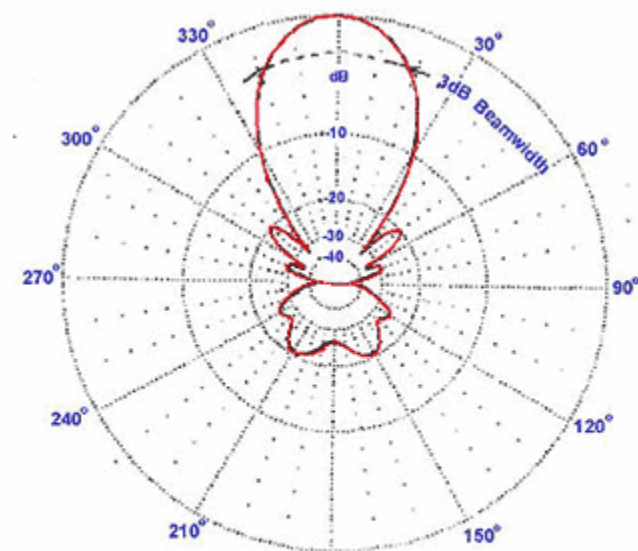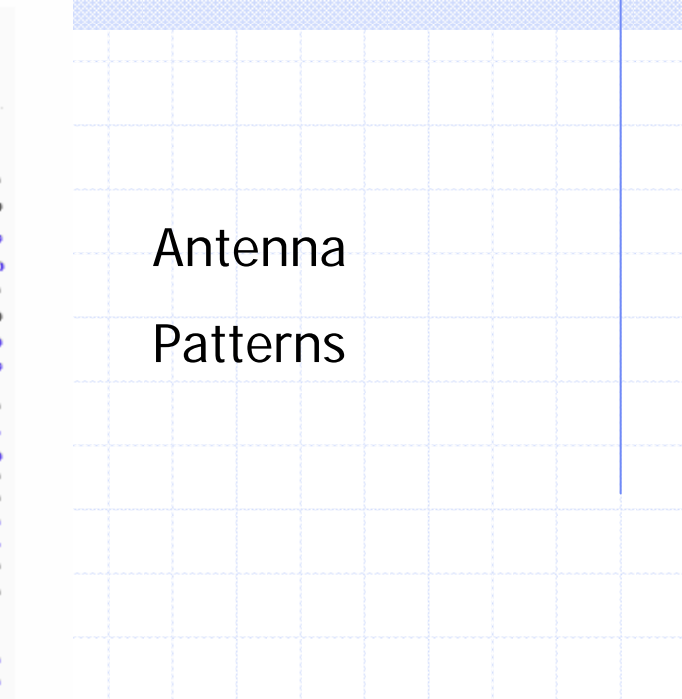Figure 1.
This figure shows a rectangular azimuth ("E" plane) plot
presentation of a typical 10 element Yagi. The detail is
good
but the pattern shape is not always apparent.
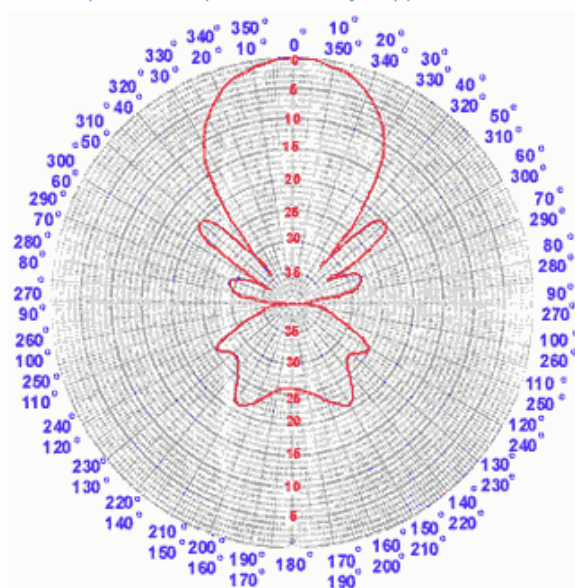
Figure 2.
This is a polar plot of the same 10 element Yagi and is
similar
to a compass rose. Therefore it is more compatible with
maps
and directions. Note that it shows the sidelobes of the
antenna relative to the main beam in decibels. This type
of plot is
preferred when the exact level of the sidelobes is
important.
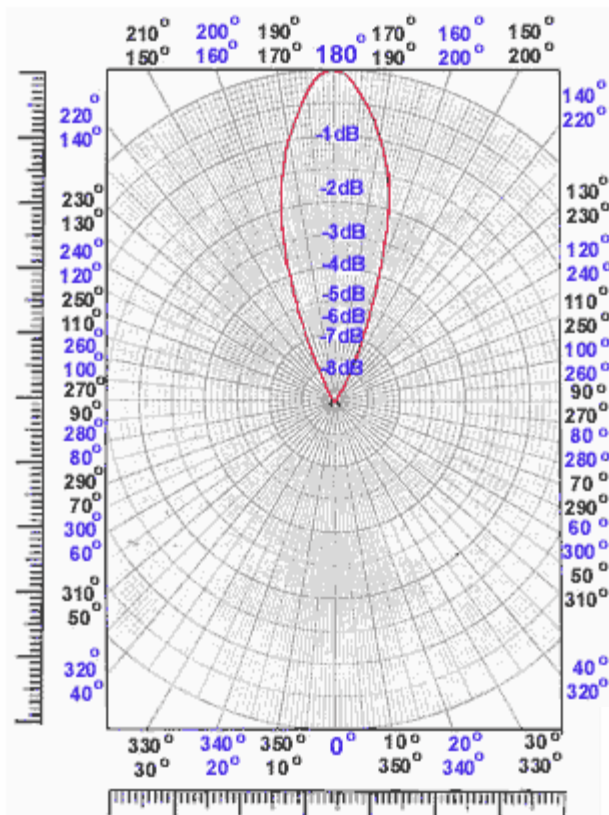
Figure 3.
This is a linear plot of the same 10 element Yagi. Note
emphasizes the shape of the main radiation lobe of the
antenna
while suppressing all side lobes making the radiation
pattern
look better than it really is!

Antenna

Patterns

Fields and Waves I

Figure 4.
This is a modified logarithmic plot of the same 10 element
Yagi which emphasizes the shape of the major beam while
compressing very low-level (>30 dB) sidelobes towards the
center of the pattern.

Yagi Antenna

5.8GHz

10 Element Yagi

http://www.astronwireless.com/library.html
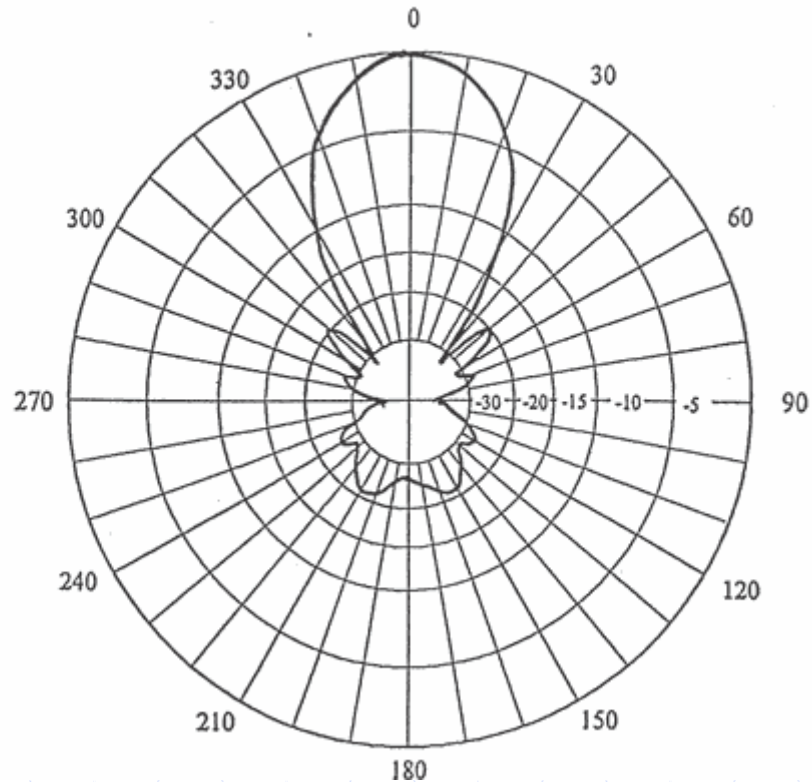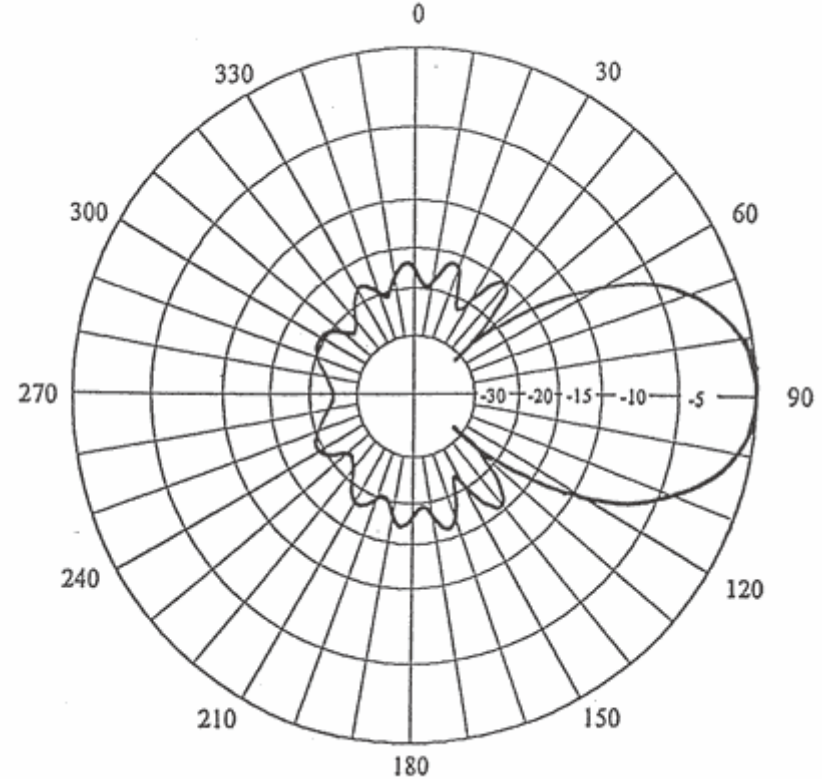
Quasi Yagi

Model

The broadband Quasi-Yagi antenna is a microstrip antenna with a truncated ground plane, which eliminates the need for a reflector, resulting in a very compact design (approximately $\lambda/2 \times \lambda/2$). The microstrip passes through a splitter curcuit to excite the 2 dipole arms out of phase. The near-field distribution shows clearly that the desired mode has been excited along the microstrip line.

Simulation

The substrait has a permitivity (εr=10.2 which reduces the freespace wavelength in the layer, such that the grid step has to be chosen accordingly. The minimum grid step is chosen small enough to resolve the fine geometry of the splitter curcuit. A broadband simulation is then run.
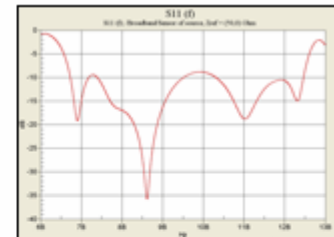
Results

The near-field distribution shows clearly that the desired mode has been excited along the microstrip line. The reflection coefficient shows that the antenna has a bandwidth of about 5 GHz.
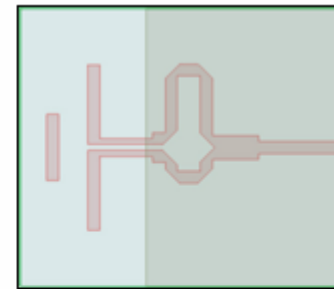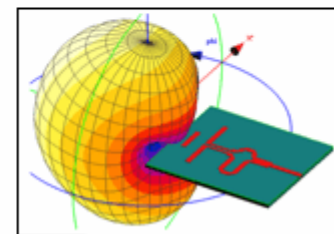
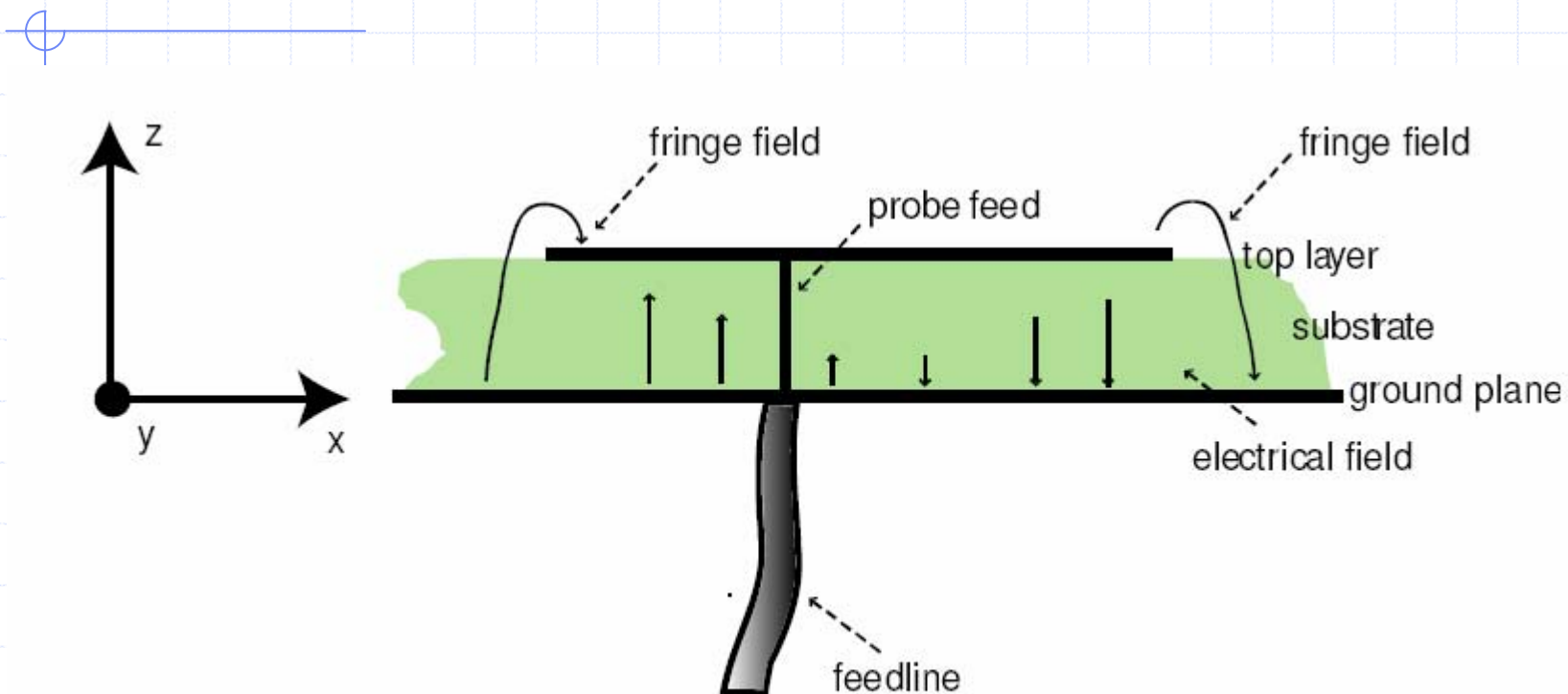

Antenna geometry
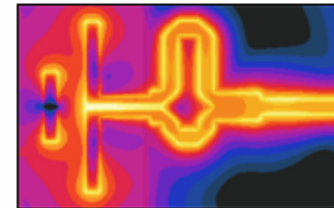
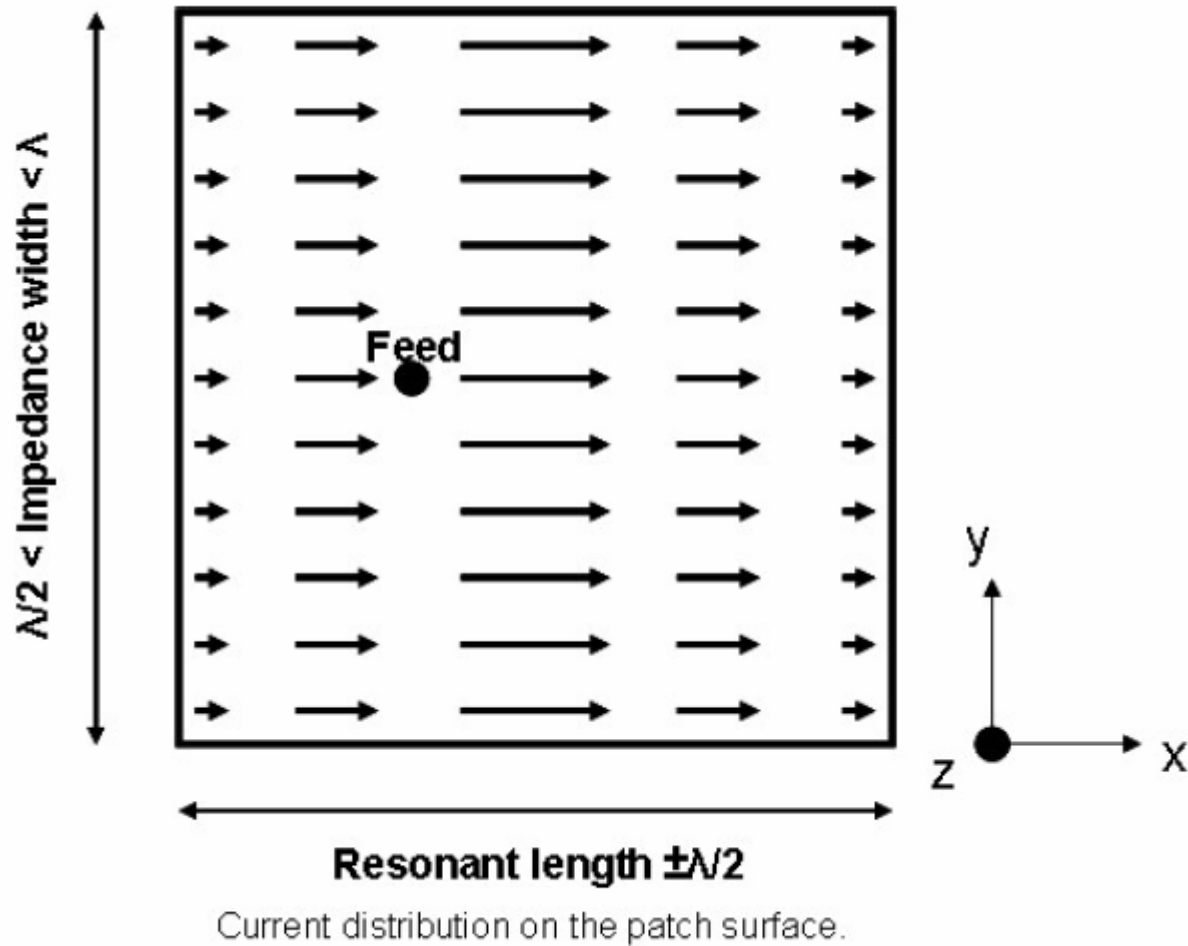*E-field distribution, 10 GHz*

S11 reflection coefficient

Far-field pattern, 10 GHz

Patch Antenna

Patch Antenna

$$L \approx 0.49 \, \lambda_d = 0.49 \, \frac{\lambda_0}{\sqrt{\varepsilon_r}} \, .$$

Current distribution on the patch surface.

Patch Antenna

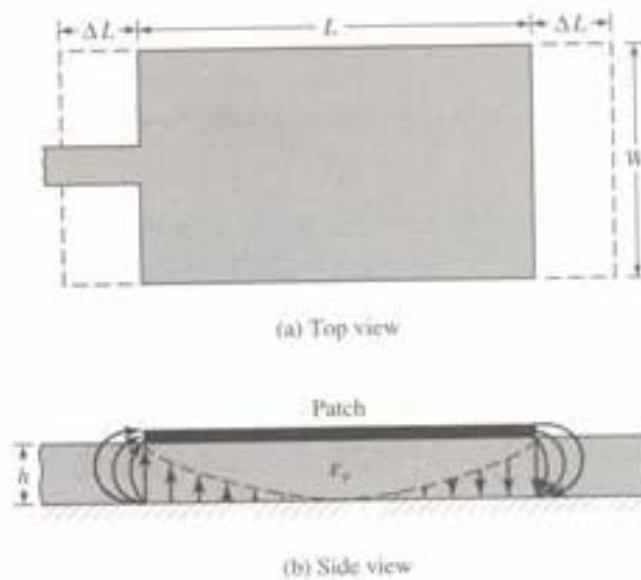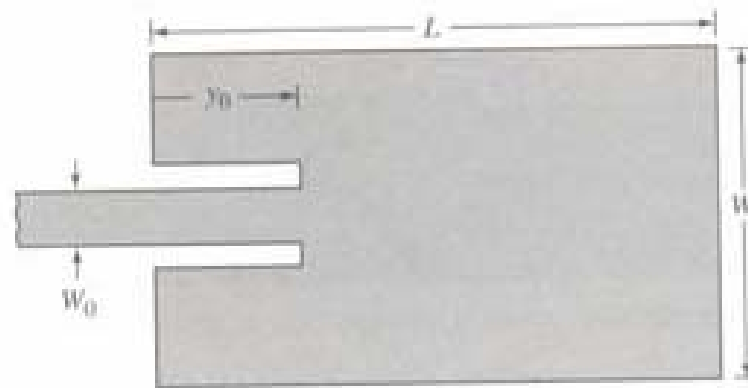(a) Top view

(b) Side view

Figure 1: Physical and effective lengths of Rectangular microstrip patch

Patch Antenna

(a) Recessed microstrip-line feed

Figure 2: Recessed microstrip-line feed

$$E_\phi = -j2V_o w k_o \frac{e^{-jk_o r}}{4\pi r} F(\theta, \phi)$$

$$E_\theta = 0$$

$$\text{where, } F(\theta, \phi) = \frac{\sin(\dfrac{k_o h}{2} \sin\theta\cos\phi)}{\dfrac{k_o h}{2} \sin\theta\cos\phi} \cdot \frac{\sin(\dfrac{k_o w}{2}\cos\theta)}{\dfrac{k_o w}{2}\cos\theta} \sin\theta$$

'r' is the distance between the far field and the origin for a single slot.

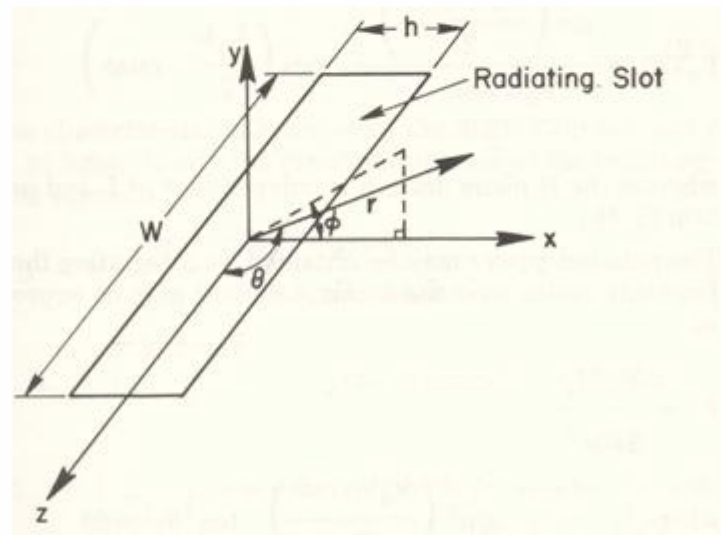'V_o' is the voltage across the slot which is invariant with x over its width.
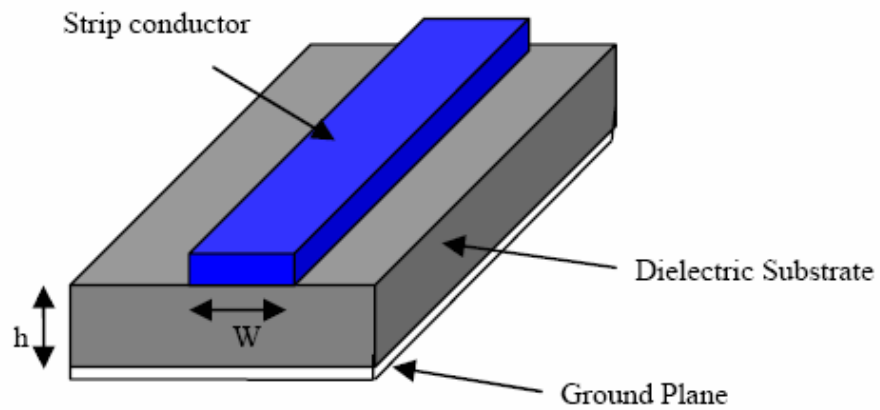

Figure 3: Radiation pattern

Strip conductor

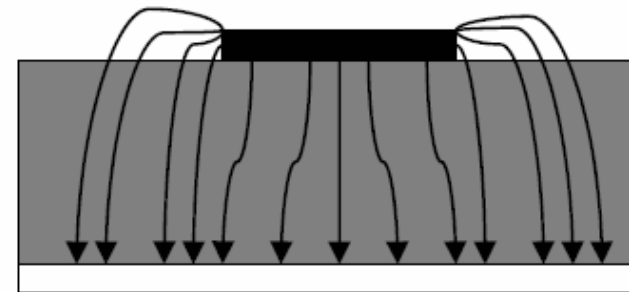Dielectric Substrate

Ground Plane

h

W

Figure 3.7 Microstrip Line

Figure 3.8 Electric Field Lines

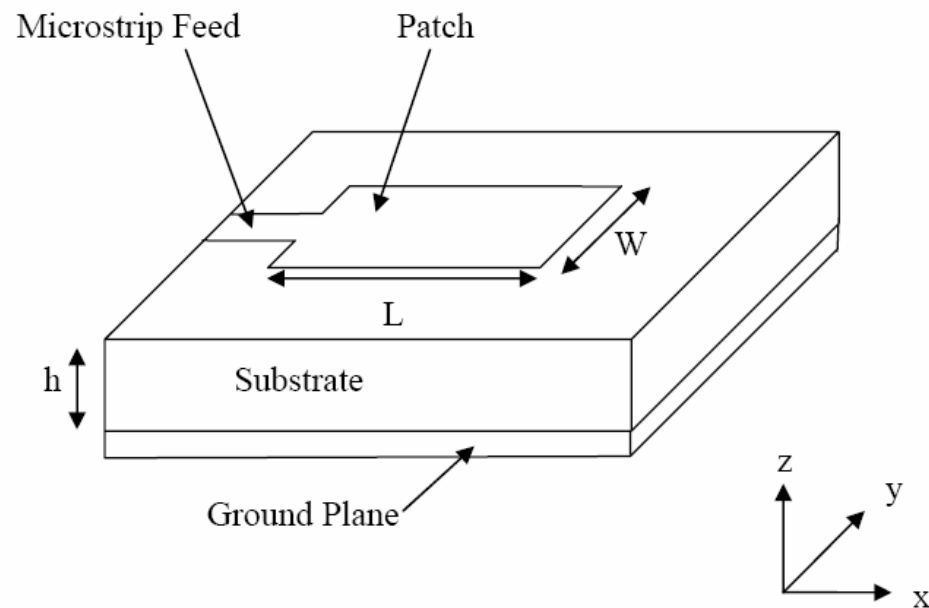Microstrip Feed   Patch

W

L

Substrate

h

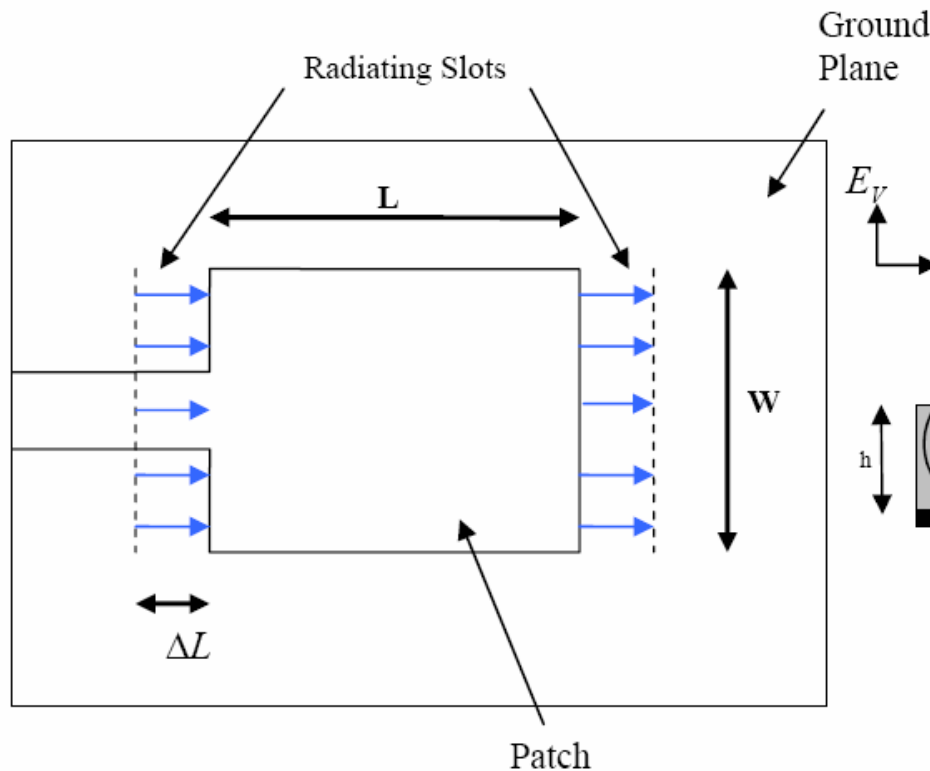Ground Plane

z
y
x

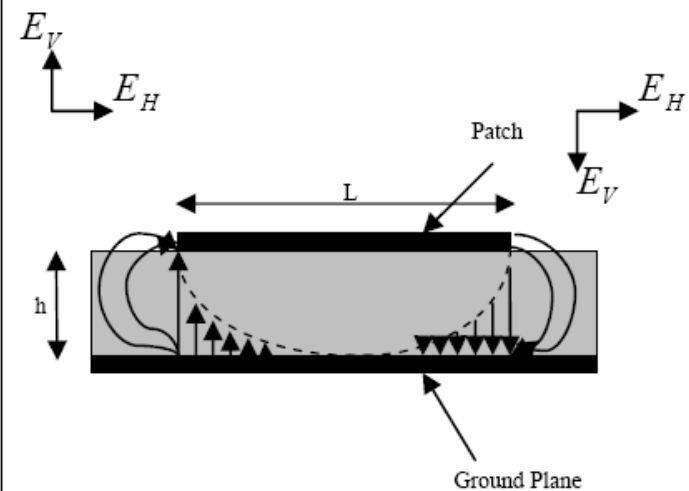Figure 3.9 Microstrip Patch Antenna

Figure 3.10 Top View of Antenna

Figure 3.11 Side View of Antenna

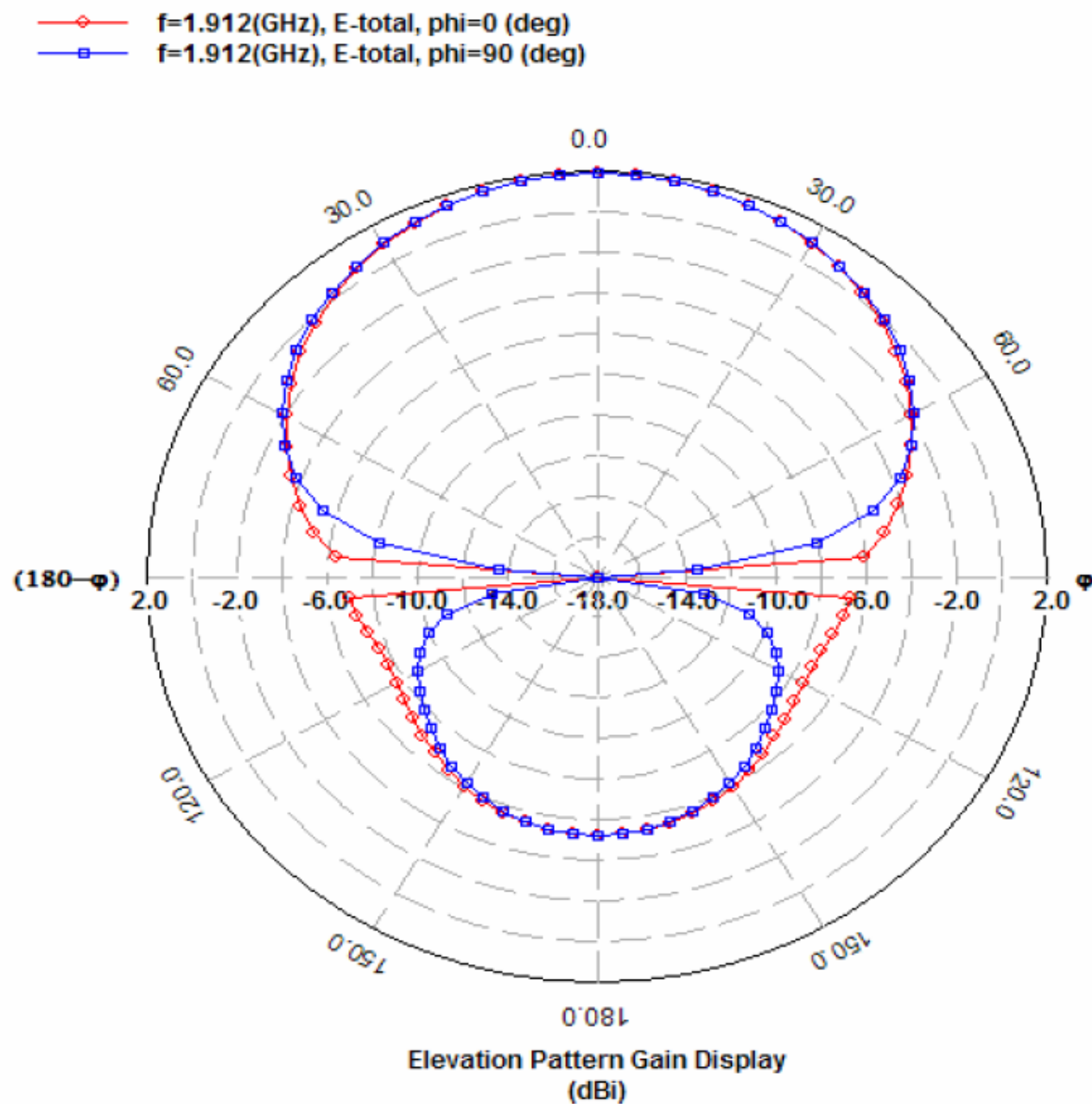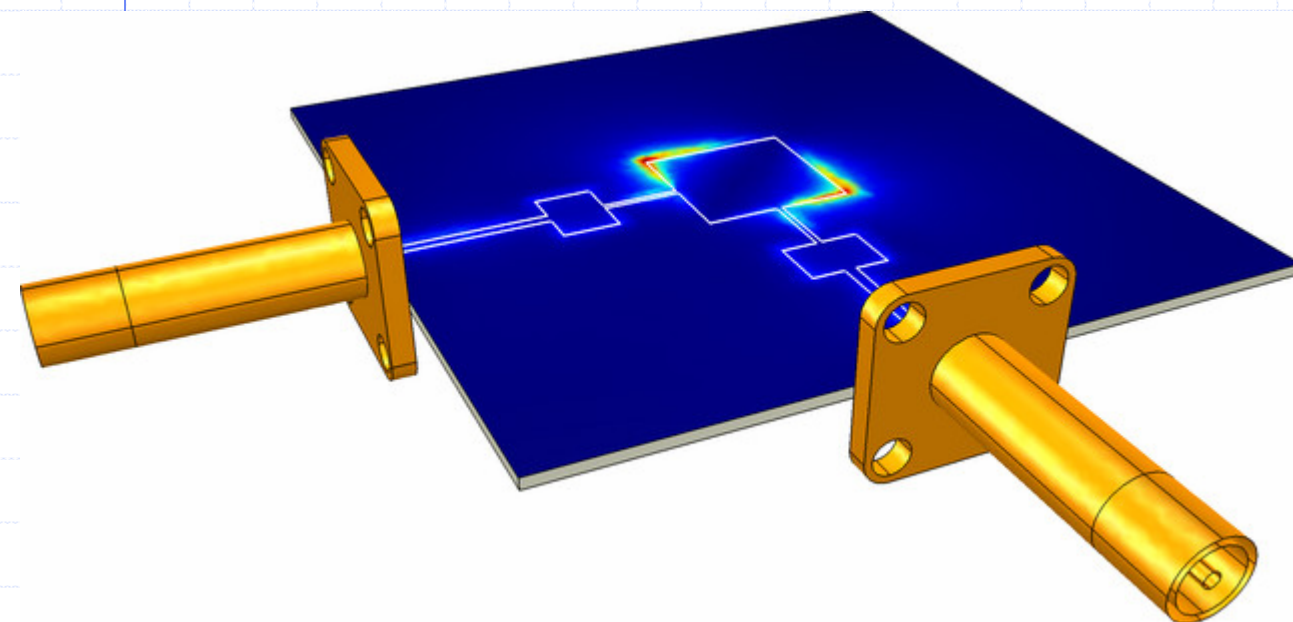http://etd.lib.fsu.edu/theses/available/etd-04102004-143656/unrestricted/Chapter4.pdf

Figure 4.5 Elevation Pattern for $\phi = 0$ and $\phi = 90$ degrees

Feed 1

Feed 2

$0°$

$±90°$
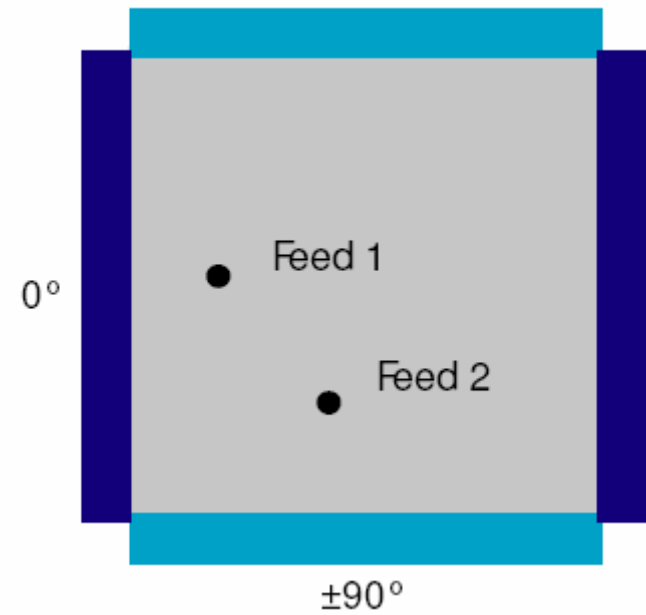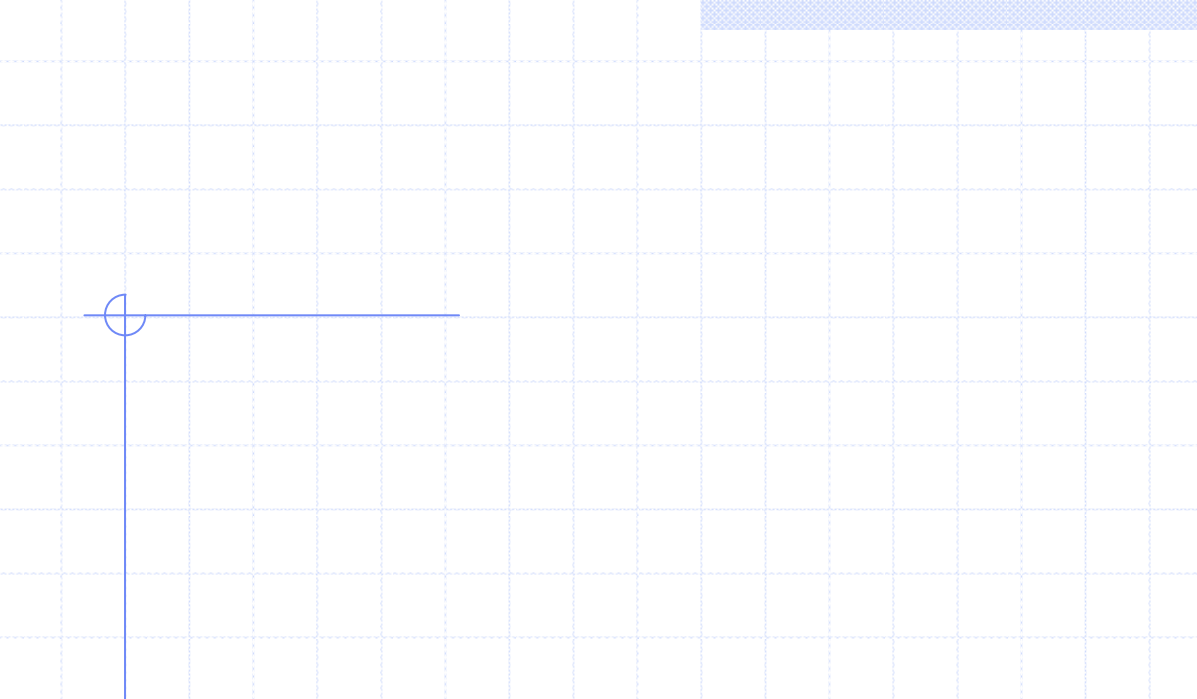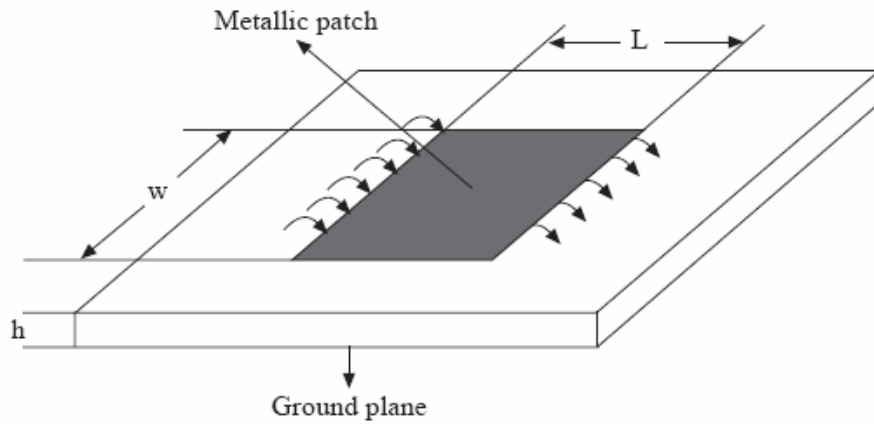
Figure 1. A rectangular patch antenna.

w = 5.516 cm
h = 1 mm
ε_r = 2.2
a = 2.758 cm
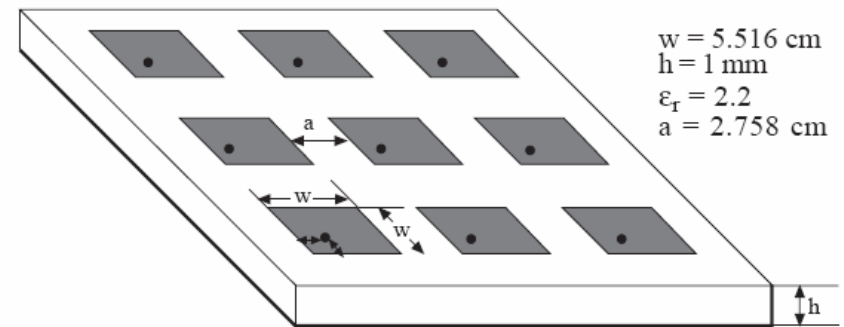
Figure 3. The 3×3 patch array that operates at 1.8 GHz, and with 35° beamwidth.

http://journals.tubitak.gov.tr/elektrik/issues/elk-05-13-1/elk-13-1-7-0407-7.pdf

w = 5.52 cm

h = 1mm

ε_r = 2.2

a = 2.758 cm

Figure 2. The square patch element and the dimensions.

Antenna Polarization

A linear polarized antenna radiates wholly in one plane containing the direction of propagation. In a circular polarized antenna, the plane o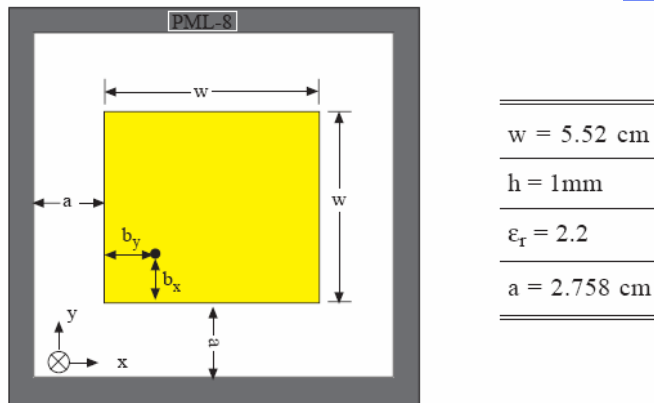f polarization rotates in a circle making one complete revolution during one period of the wave. If the rotation is clockwise looking in the direction of propagation, the sense is called right-hand-circular (RHC). If the rotation is counterclockwise, the sense is called left-hand-circular (LHC).

An antenna is said to be vertically polarized (linear) when its electric field is perpendicular to the Earth's surface. An example of a vertical antenna is a broadcast tower for AM radio or the "whip" antenna on an automobile.

Antenna Polarization Application Note
By Joseph H. Reisert

http://www.astronwireless.com/polarization.html

Antenna Polarization

Horizontally polarized (linear) antennas have their electric field parallel to the Earth's surface. Television transmissions in the USA use horizontal polarization.

A circular polarized wave radiates energy in both the horizontal and vertical planes and all planes in between. The difference, if any, between the maximum and the minimum peaks as the antenna is rotated through all angles, is called the axial ratio or ellipticity and is usually specified in decibels (dB). If the axial ratio is near 0 dB, the antenna is said to be circular polarized. If the axial ratio is greater than 1-2 dB, the polarization is often referred to as elliptical.

Antenna Polarization Application Note
By Joseph H. Reisert

http://www.astronwireless.com/polarization.html

Antenna Polarization

In the early days of FM radio in the 88-108 MHz spectrum, the radio stations broadcasted horizontal polarization. However, in the 1960's, FM radios became popular in automobiles which used vertical polarized receiving whip antennas. As a result, the FCC modified Part 73 of the rules and regulations to allow FM stations to broadcast RHC or elliptical polarization to improve reception to vertical receiving antennas as long as the horizontal component was dominant.

Antenna Polarization Application Note
By Joseph H. Reisert

http://www.astronwireless.com/polarization.html

Antenna Polarization

Circular polarization is most often use on satellite communications. This is particularly desired since the polarization of a linear polarized radio wave may be rotated as the signal passes through any anomalies (such as Faraday rotation) in the ionosphere. Furthermore, due to the position of the Earth with respect to the satellite, geometric differences may vary especially if the satellite appears to move with respect to the fixed Earth bound station. Circular polarization will keep the signal constant regardless of these anomalies.

Antenna Polarization Application Note
By Joseph H. Reisert

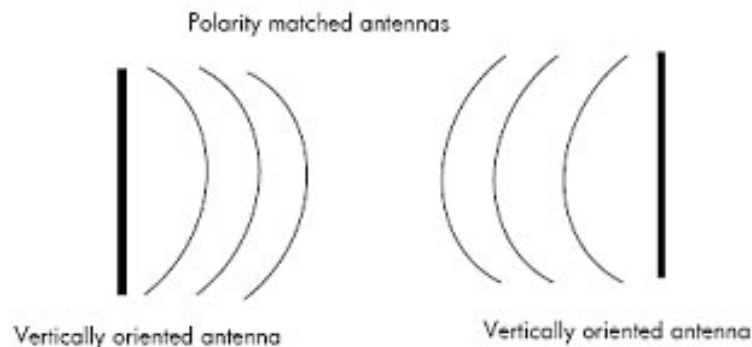http://www.astronwireless.com/polarization.html

Antenna Polarization

Why is a TV signal horizontally polarized?

Because man-made noise is predominantly vertically polarized.

Do the transmitting and receiving antennas need to have the same polarization?
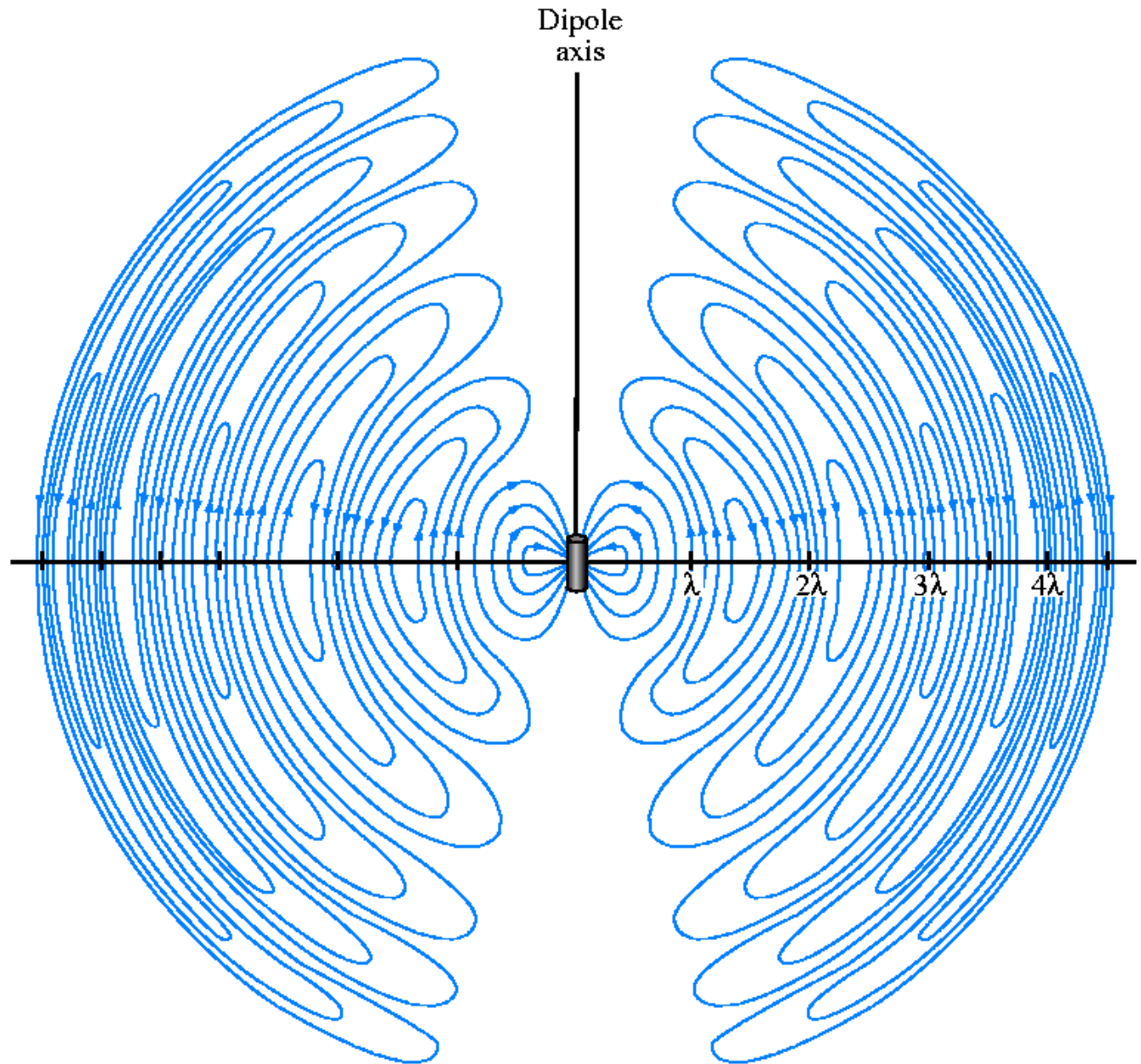
Yes.

Polarity matched antennas

Vertically oriented antenna   Vertically oriented antenna

http://www.hp.com/rnd/pdf_html/antenna.htm

Antennas

The simplest antenna is the Hertzian dipole, which looks like the following figure with the antenna axis aligned with the z direction in spherical coordinates.

Transmission Line
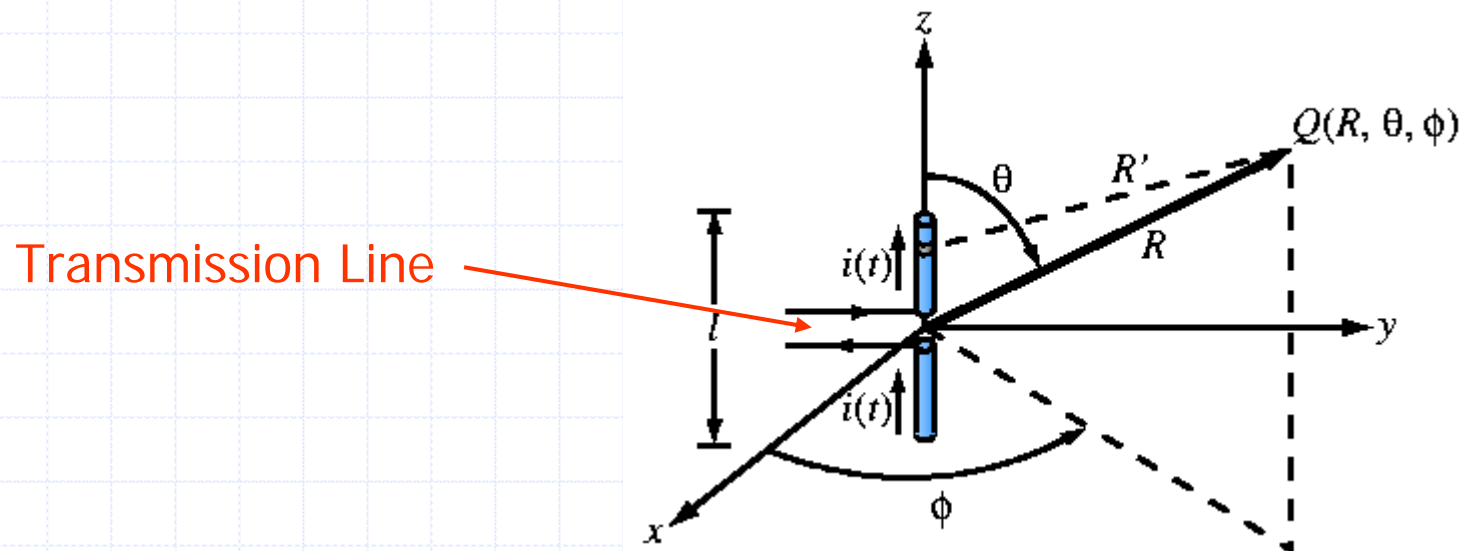
Antennas

The electric field around the Hertzian dipole – note the vertical polarization

Antennas

Power is radiated horizontally, which is a good thing since this means that such antennas can easily communicate with one another on the surface of the earth. The range in angle is more than sufficient to handle the small elevation changes that characterize the earth's surface.
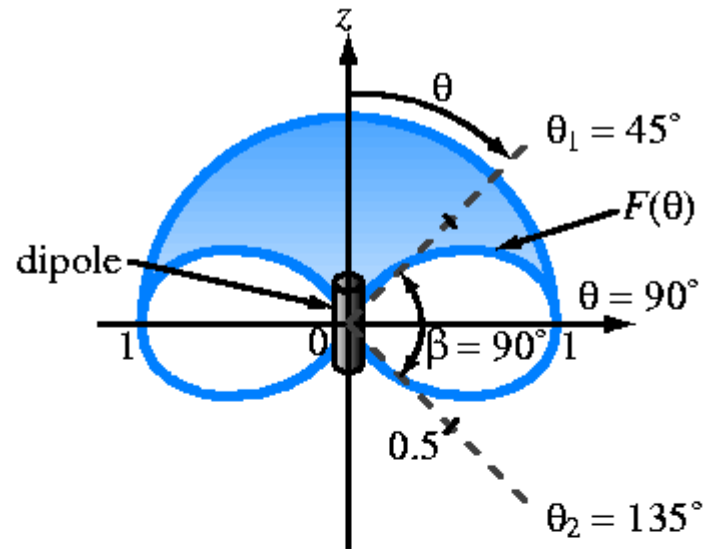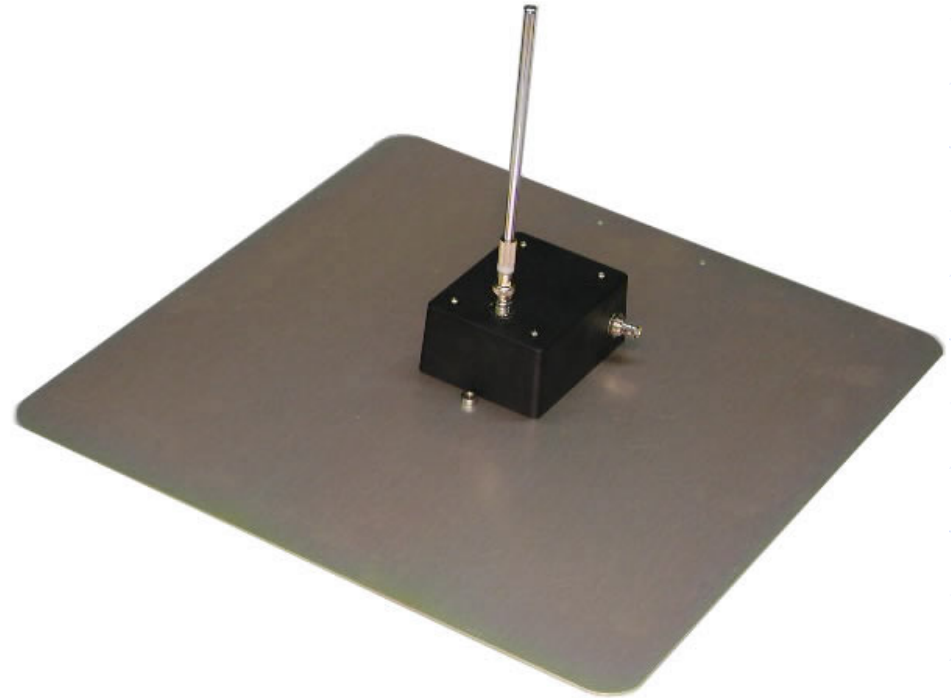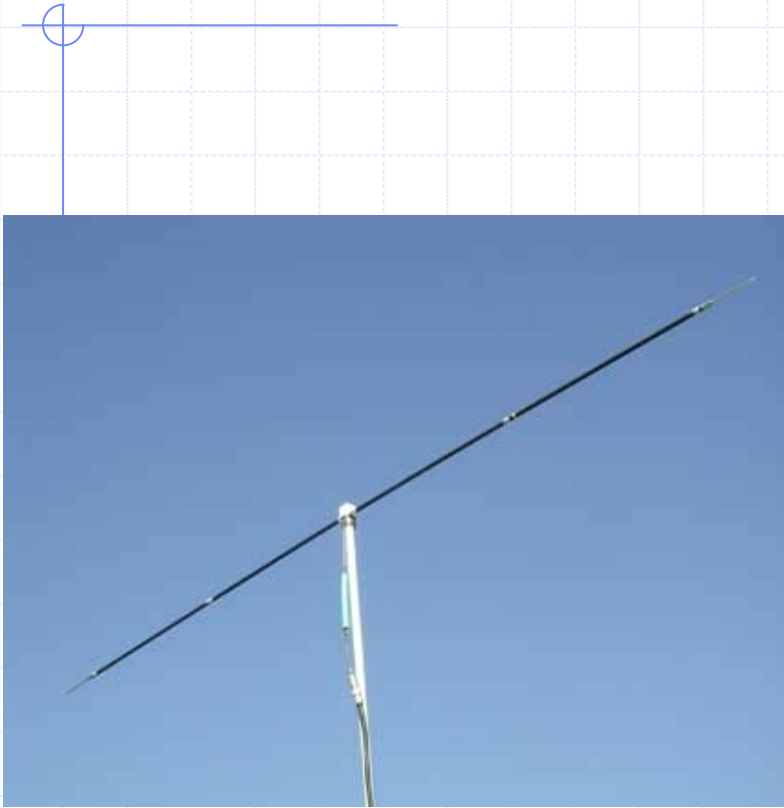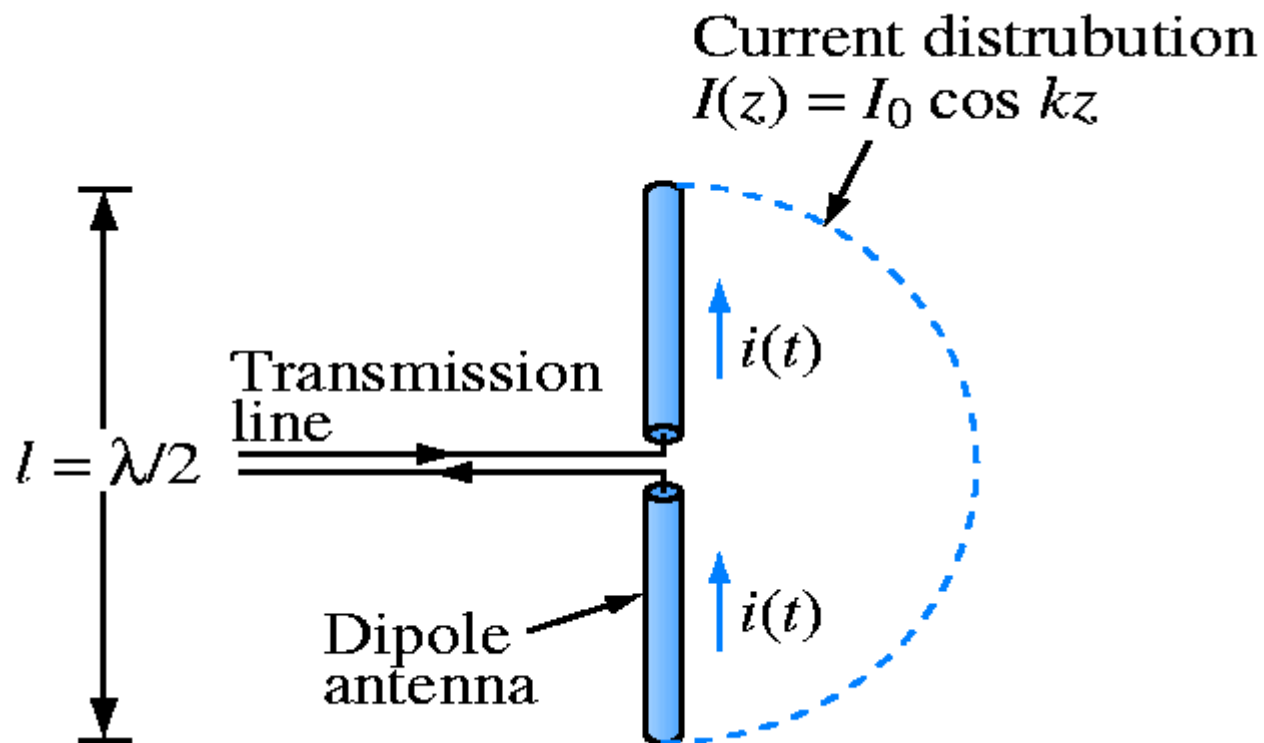

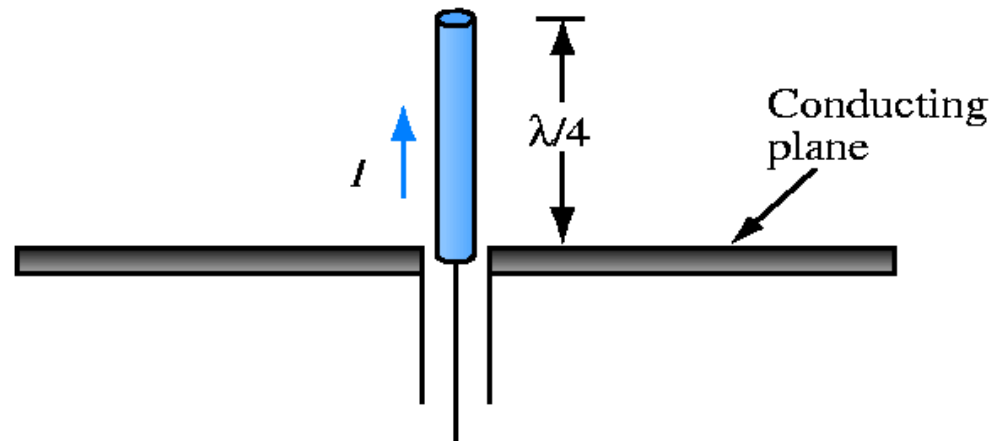(a) Elevation pattern
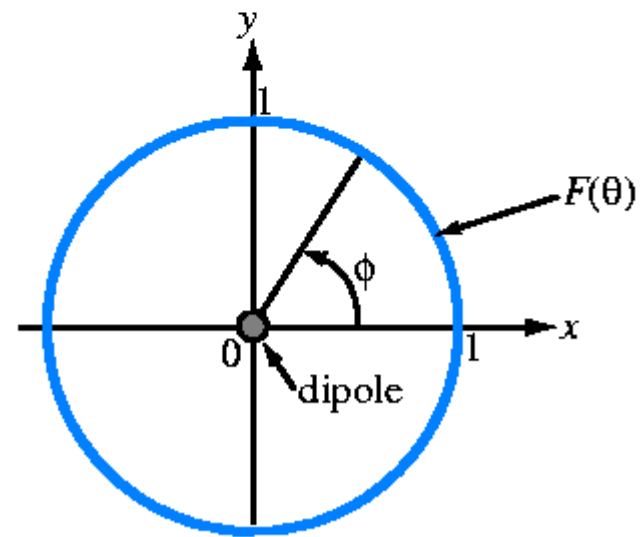
(b) Azimuth pattern

Antennas – Half Wave Dipole vs Quarter Wave Monopole
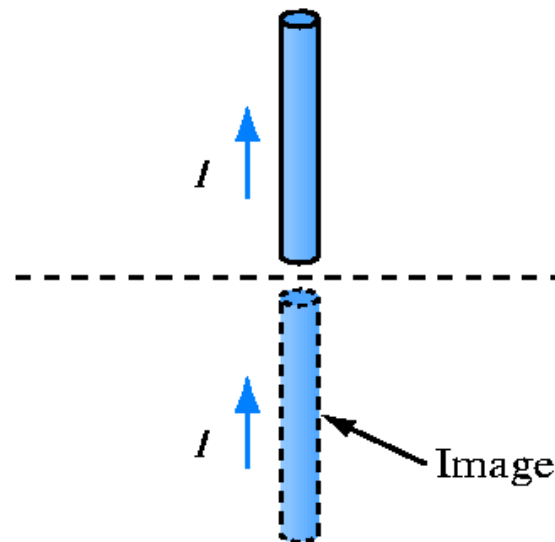
Antennas – Half Wave Dipole vs Quarter Wave Monopole

Current distrubution
$$I(z) = I_0 \cos kz$$

$i(t)$

Transmission line

$l = \lambda/2$

Dipole antenna

$i(t)$

Antennas – Half Wave Dipole vs Quarter Wave Monopole

Conducting plane

$\lambda/4$

I

(a)

I

I

Image

Figure 9-15

(b)

Bertoni Slides

- Extensive Slides on Propagation, Etc for Wireless http://eeweb1.poly.edu/faculty/bertoni/el675.html