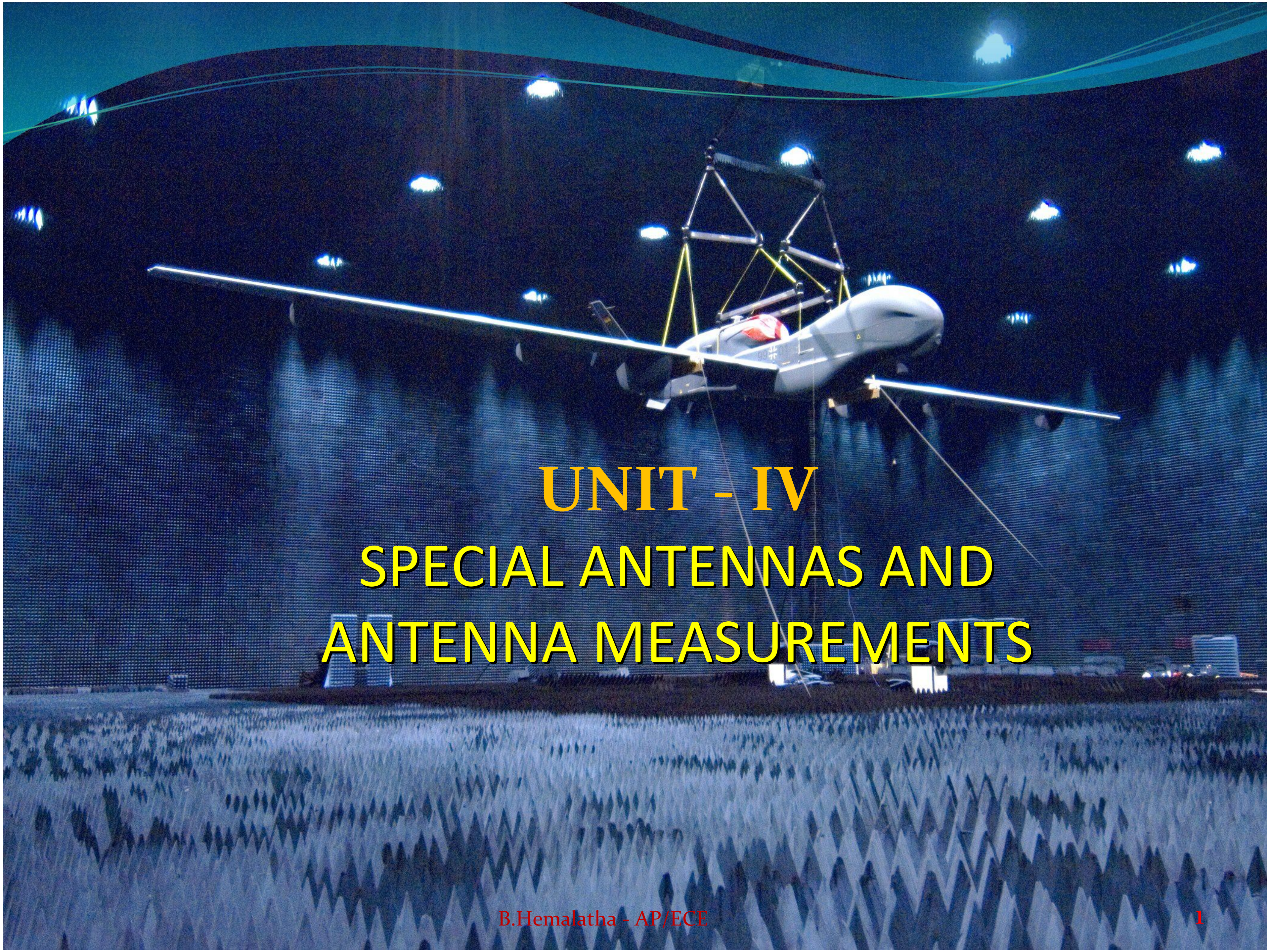


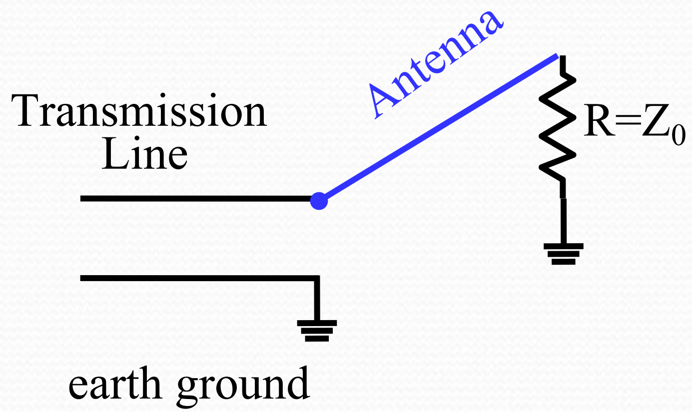
UNIT - IV

SPECIAL ANTENNAS AND ANTENNA MEASUREMENTS

Elementary Antennas

low cost – flexible solutions

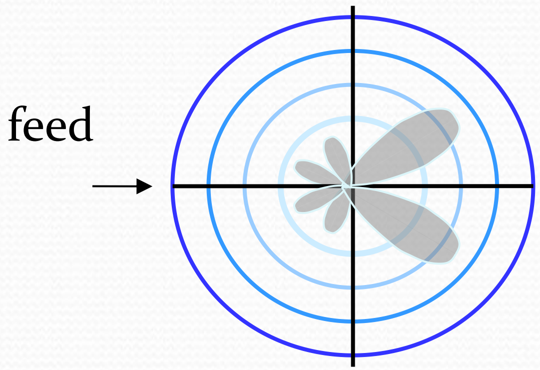
Long Wire Antenna



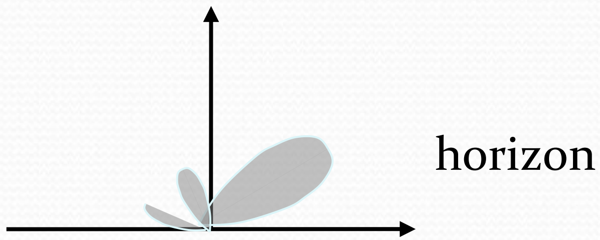
- effective wideband antenna
- length l = several wavelengths
  - used for signals with $0.1l < \lambda < 0.5l$
  - frequency span = 5:1
- drawback for band limited systems - unavoidable interference
- near end driven by ungrounded transmitter output
- far end terminated by resistor
  - typically several hundred Ω
  - impedance matched to antenna Z_0
- transmitter electrical circuit ground connected to earth
- practically - long wire is a lossy transmission line
  - terminating resistor prevent standing waves

Polar radiation pattern

- 2 main lobes
  - on either side of antenna
  - pointed towards antenna termination
- smaller lobes on each side of antenna – pointing forward & back
- radiation angle 45° (depending on height) → useful for sky waves



Polar ration pattern



Angular radiation pattern

Poor Efficiency:

Transmit power

-50% of transmit power radiated

-50% dissapated in termination resistor

Receive power

-50% captured EM energy converted to signal for reciever

- 50% absorbed by terminating resistor

TYPES OF ANTENNAS

- According to their applications and technology available, antennas generally fall in one of two categories:

1. Omnidirectional or only weakly directional antennas which receive or radiate more or less in all directions. These are employed when the relative position of the other station is unknown or arbitrary. They are also used at lower frequencies where a directional antenna would be too large, or simply to cut costs in applications where a directional antenna isn't required.

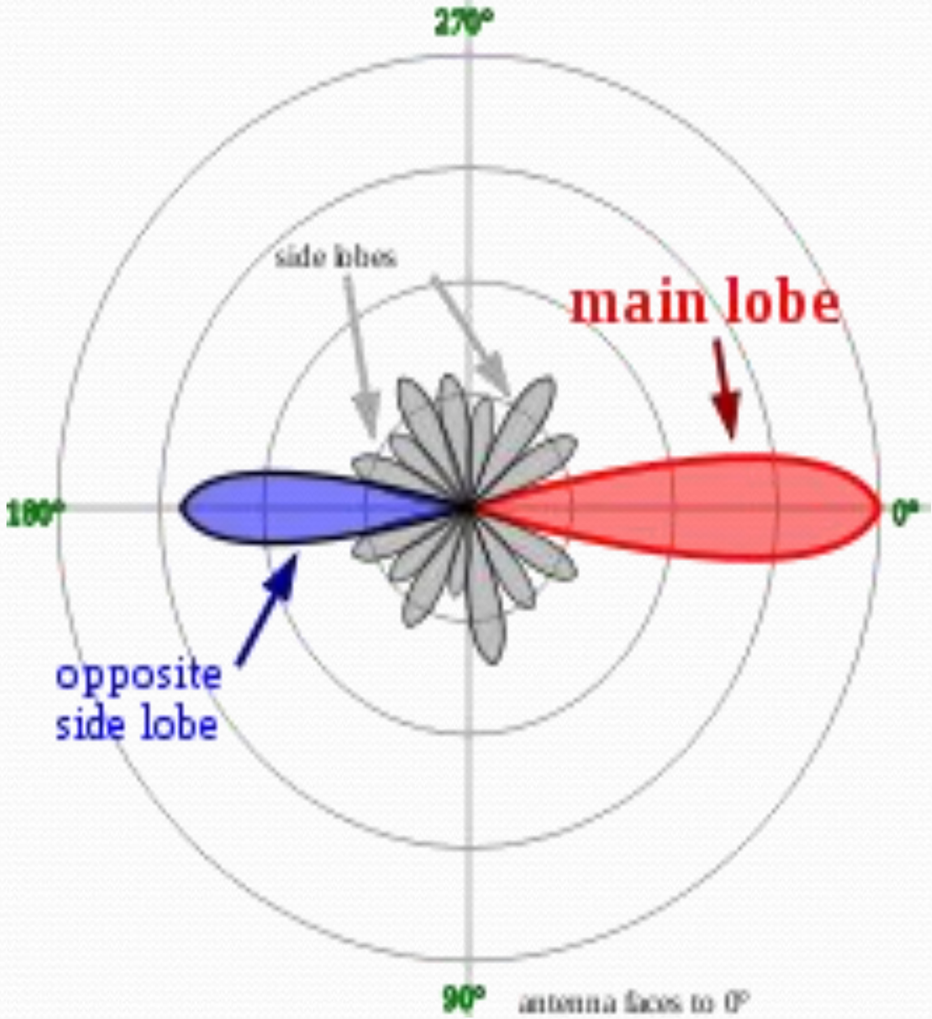
2. Directional or *beam* antennas which are intended to preferentially radiate or receive in a particular direction or directional pattern.

- According to length of transmission lines available, antennas generally fall in one of two categories:

1. Resonant Antennas – is a transmission line, the length of which is exactly equal to multiples of half wavelength and it is open at both ends.

2. Non-resonant Antennas – the length of these antennas is not equal to exact multiples of half wavelength. In these antennas standing waves are not present as antennas are terminated in correct impedance which avoid reflections. The waves travel only in forward direction .Non-resonant antenna is a unidirectional antenna.

RADIATION PATTERN



- The radiation pattern of an antenna is a plot of the relative field strength of the radio waves emitted by the antenna at different angles.
- It is typically represented by a three dimensional graph, or polar plots of the horizontal and vertical cross sections. It is a plot of field strength in V/m versus the angle in degrees.
- The pattern of an ideal isotropic antenna , which radiates equally in all directions, would look like a sphere.
- Many non-directional antennas, such as dipoles, emit equal power in all horizontal directions, with the power dropping off at higher and lower angles; this is called an omni directional pattern and when plotted looks like a donut.

- The radiation of many antennas shows a pattern of maxima or "*lobes*" at various angles, separated by “ *nulls*", angles where the radiation falls to zero.

- This is because the radio waves emitted by different parts of the antenna typically interfere, causing maxima at angles where the radio waves arrive at distant points in phase, and zero radiation at other angles where the radio waves arrive out of phase.

- In a directional antenna designed to project radio waves in a particular direction, the lobe in that direction is designed larger than the others and is called the "*main lobe*".

- The other lobes usually represent unwanted radiation and are called “*sidelobes*". The axis through the main lobe is called the "*principle axis*" or “*boresight axis*".

ANTENNA GAIN

- Gain is a parameter which measures the degree of directivity of the antenna's radiation pattern. A high-gain antenna will preferentially radiate in a particular direction.

- Specifically, the *antenna gain*, or *power gain* of an antenna is defined as the ratio of the intensity (power per unit surface) radiated by the antenna in the direction of its maximum output, at an arbitrary distance, divided by the intensity radiated at the same distance by a hypothetical isotropic antenna.

- The gain of an antenna is a passive phenomenon - power is not added by the antenna, but simply redistributed to provide more radiated power in a certain direction than would be transmitted by an isotropic antenna.

- High-gain antennas have the advantage of longer range and better signal quality, but must be aimed carefully in a particular direction.

- Low-gain antennas have shorter range, but the orientation of the antenna is relatively inconsequential.

- For example, a dish antenna on a spacecraft is a high-gain device that must be pointed at the planet to be effective, whereas a typical Wi-Fi antenna in a laptop computer is low-gain, and as long as the base station is within range, the antenna can be in any orientation in space.

- In practice, the half-wave dipole is taken as a reference instead of the isotropic radiator. The gain is then given in **dBd** (decibels over **d**ipole)

ANTENNA EFFICIENCY

- Efficiency of a transmitting antenna is the ratio of power actually radiated (in all directions) to the power absorbed by the antenna terminals.

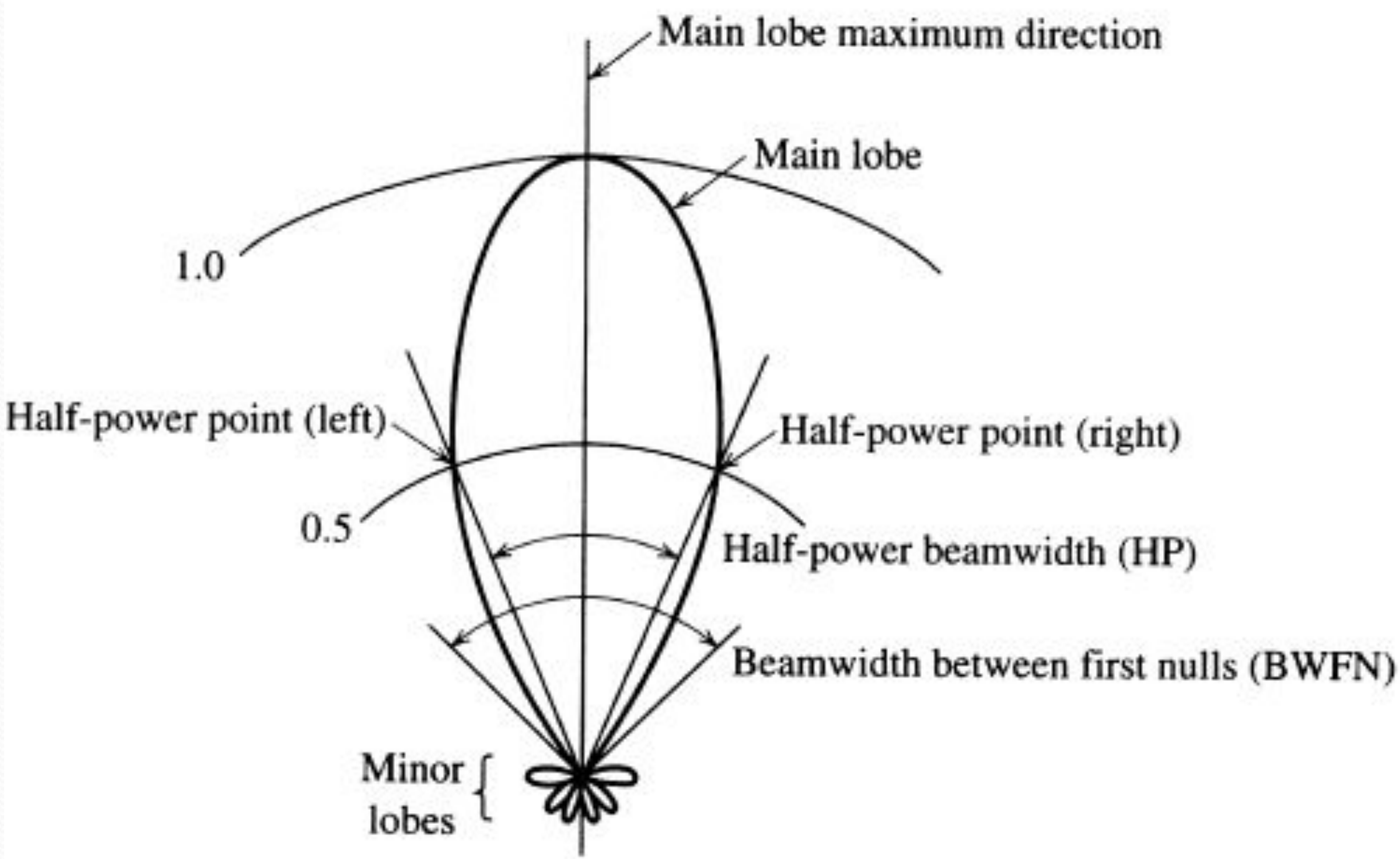
- The power supplied to the antenna terminals which is not radiated is converted into heat. This is usually through loss resistance in the antenna's conductors, but can also be due to dielectric or magnetic core losses in antennas (or antenna systems) using such components.

POLARIZATION

- The polarization of an antenna is the orientation of the electric field (E-plane) of the radio wave with respect to the Earth's surface and is determined by the physical structure of the antenna and by its orientation.
- A simple straight wire antenna will have one polarization when mounted vertically, and a different polarization when mounted horizontally.
- Reflections generally affect polarization. For radio waves the most important reflector is the ionosphere - signals which reflect from it will have their polarization changed
- LF,VLF and MF antennas are vertically polarized

BEAM-WIDTH

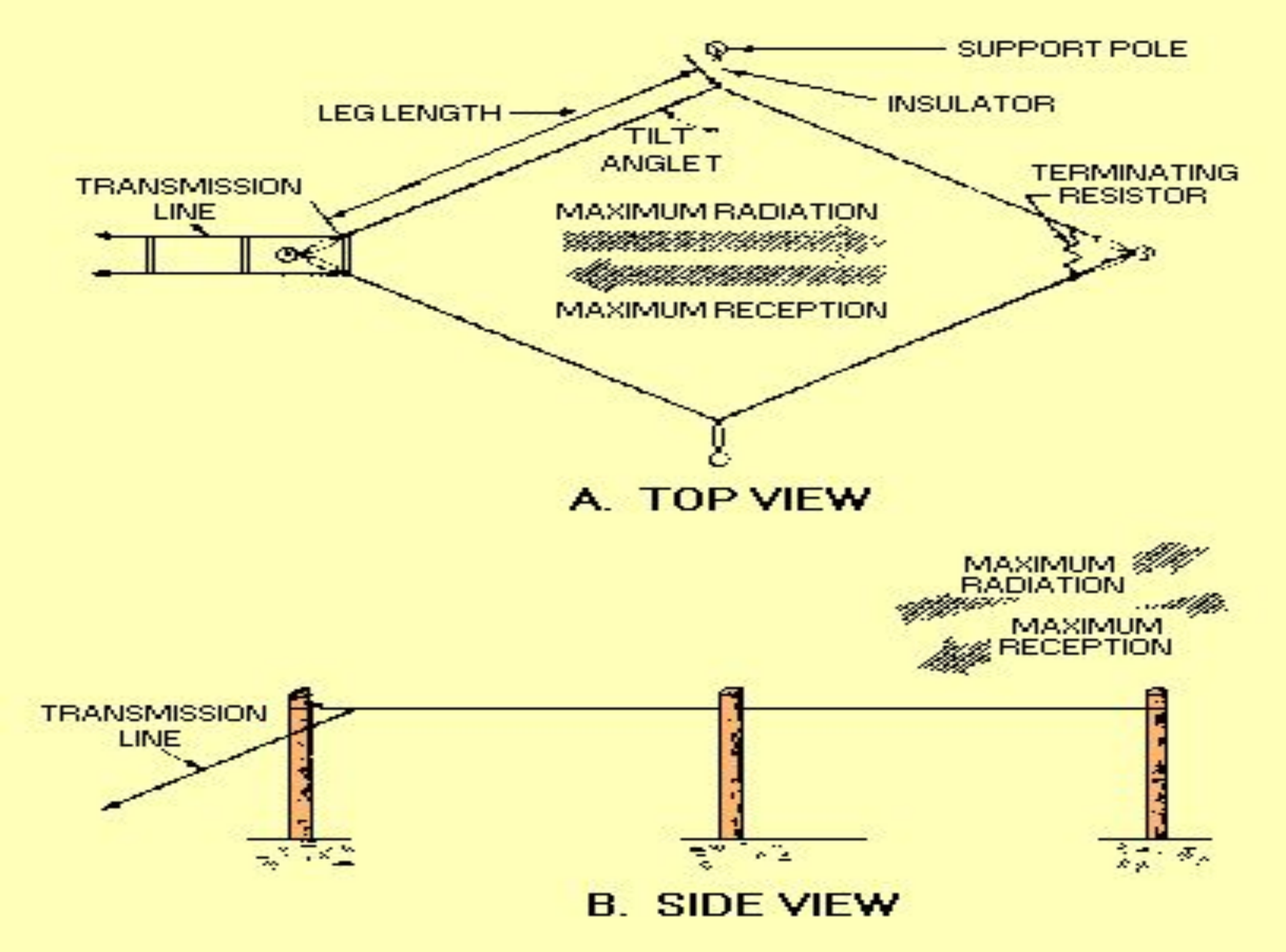
- Beam-width of an antenna is defined as angular separation between the two half power points on power density radiation pattern OR
- Angular separation between two 3dB down points on the field strength of radiation pattern
- It is expressed in degrees

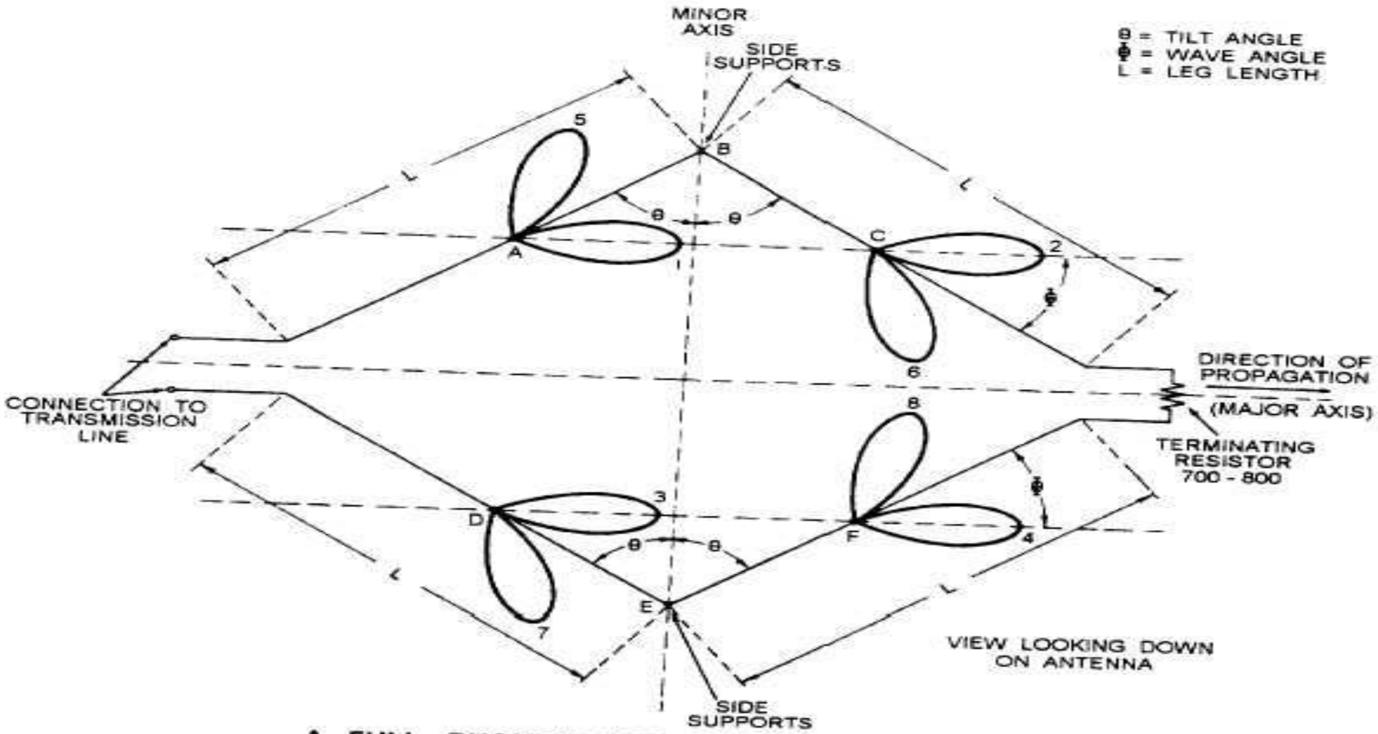

Main lobe maximum direction
Main lobe
1.0
Half-power point (left)
Half-power point (right)
0.5
Half-power beamwidth (HP)
Beamwidth between first nulls (BWFN)
Minor lobes

RHOMBIC ANTENNA

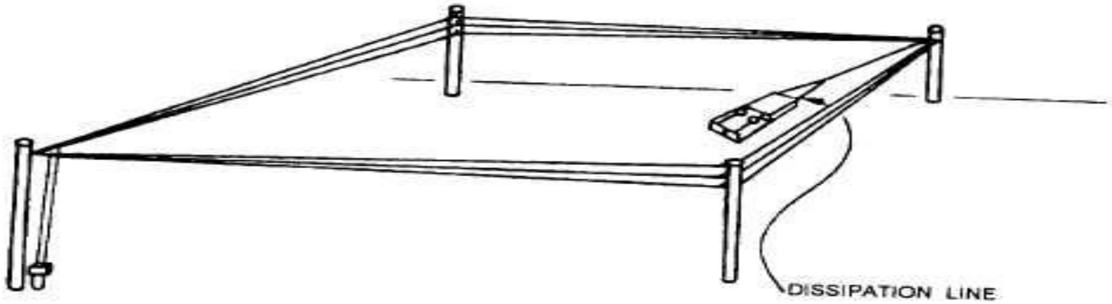
- Structure and construction
  - 4 wires are connected in rhombic shape and terminated by a resistor.
  - Mounted horizontally and placed > ^/2 from ground.

- Highest development of long wire antenna is rhombic antenna.


SUPPORT POLE
INSULATOR
LEG LENGTH
TILT ANGLE
TRANSMISSION LINE
TERMINATING RESISTOR
MAXIMUM RADIATION
MAXIMUM RECEPTION
A. TOP VIEW
MAXIMUM RADIATION
MAXIMUM RECEPTION
TRANSMISSION LINE
B. SIDE VIEW



A. FULL - RHOMBIC TRANSMITTING ANTENNA



B. NON - RESONANT HORIZONTAL THREE - WIRE RHOMBIC

35NP0013

- Advantages
  - Easier to construct
  - Its i/p impedance and radiation pattern are relatively constant over range of frequencies.
  - Maximum efficiency
  - High gain can be obtained.
- Disadvantages
  - Large site area and large side lobes.

Application

- Long distance communication, high frequency transmission and reception.
- Point to point communication.
- Radio communication.
- Short wave radio broadcasting.

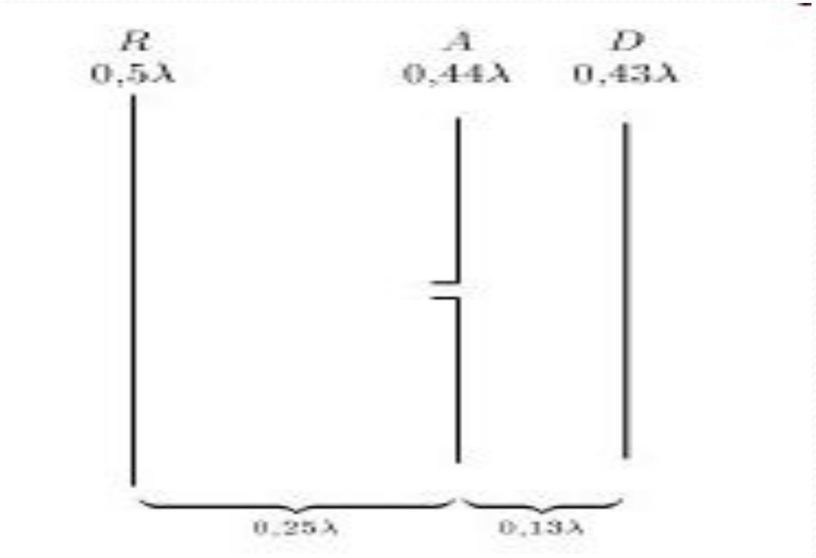
YAGI-UDA ANTENNA

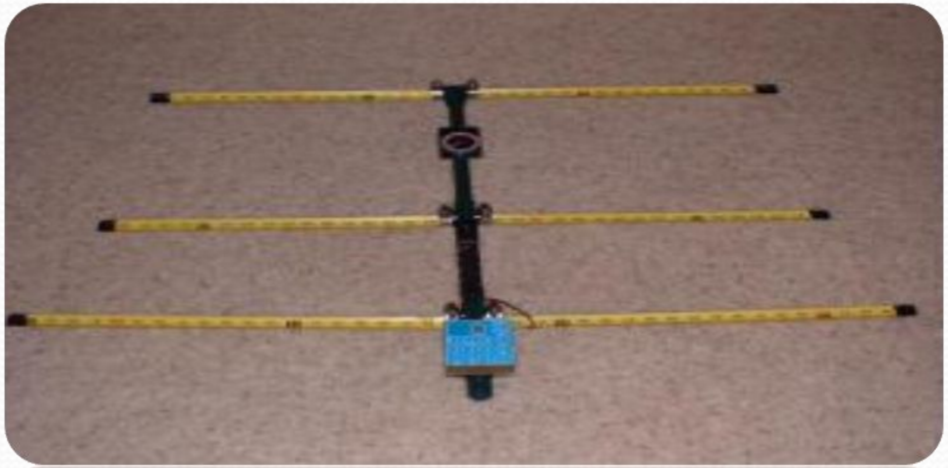
- It is a directional antenna consisting of a driven element (typically a dipole or folded dipole) and additional parasitic elements (usually a so-called *reflector* and one or more *directors*).

- All the elements are arranged collinearly and close together.

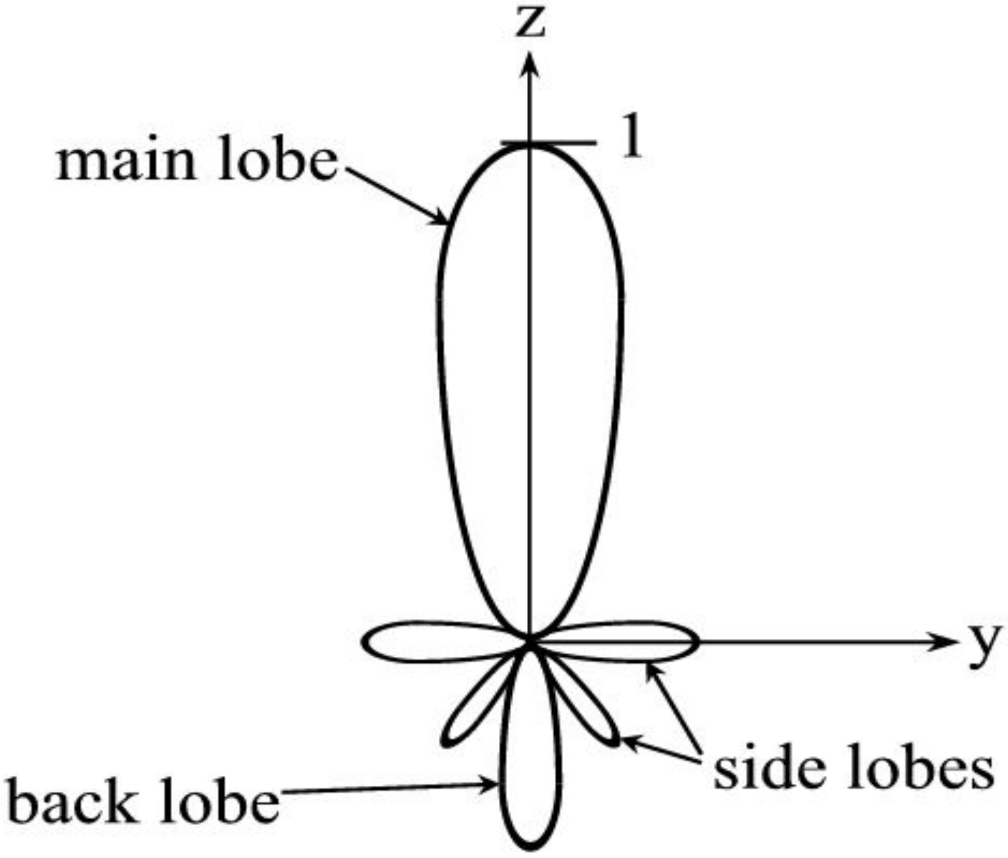
- The reflector element is slightly longer (typically 5% longer) than the driven dipole, whereas the so-called directors are a little bit shorter.

- The design achieves a very substantial increase in the antenna's directionality and gain compared to a simple dipole.


R
0,5λ
A
0,44λ
D
0,43λ
0,25λ
0,13λ



- Typical spacing between elements vary from about 1/10 to 1/4 of a wavelength, depending on the specific design.
- The elements are usually parallel in one plane.
- Radiation pattern is modified figure of eight
- By adjusting distance between adjacent directors it is possible to reduce back lobe
- Improved front to back ratio



(a)

ANTENNA APPLICATIONS

They are used in systems such as

- Radio broadcasting
- Broadcast television
- Two-way radio
- Communication receivers
- Radar
- Cell phones
- Satellite communications.

ANTENNA CONSIDERATIONS

- The space available for an antenna
- The proximity to neighbors
- The operating frequencies
- The output power
- Money

LOOP ANTENNA

- A **loop antenna** is a radio antenna consisting of a loop of wire with its ends connected to a balanced transmission line
- It is a single turn coil carrying RF current through it.
- The dimensions of coil are smaller than the wavelength hence current flowing through the coil has same phase.
- Small loops have a poor efficiency and are mainly used as receiving antennas at low frequencies. Except for car radios, almost every AM broadcast receiver sold has such an antenna built inside of it or directly attached to it.

- A technically small loop, also known as a magnetic loop, should have a circumference of one tenth of a wavelength or less. This is necessary to ensure a constant current distribution round the loop.

- As the frequency or the size are increased, a standing wave starts to develop in the current, and the antenna starts to have some of the characteristics of a folded dipole antenna or a self-resonant loop.

- Self-resonant loop antennas are larger. They are typically used at higher frequencies, especially VHF and UHF, where their size is manageable. They can be viewed as a form of folded dipole and have somewhat similar characteristics. The radiation efficiency is also high and similar to that of a dipole.

- Radiation pattern of loop antenna is a doughnut pattern.

- Can be circular or square loop

- No radiation is received normal to the plane of loop and null is obtained in this direction.

- Application: Used for direction finding applications

TURNSTILE ANTENNA

- A **turnstile antenna** is a set of two dipole antennas aligned at right angles to each other and fed 90 degrees out-of-phase.

- The name reflects that the antenna looks like a turnstile when mounted horizontally.

- When mounted horizontally the antenna is nearly omnidirectional on the horizontal plane.

FOLDED DIPOLE

- Folded antenna is a single antenna but it consists of two elements.
- First element is fed directly while second one is coupled inductively at its end.
- Radiation pattern of folded dipole is same as that of dipole antenna i.e figure of eight (8).

Advantages

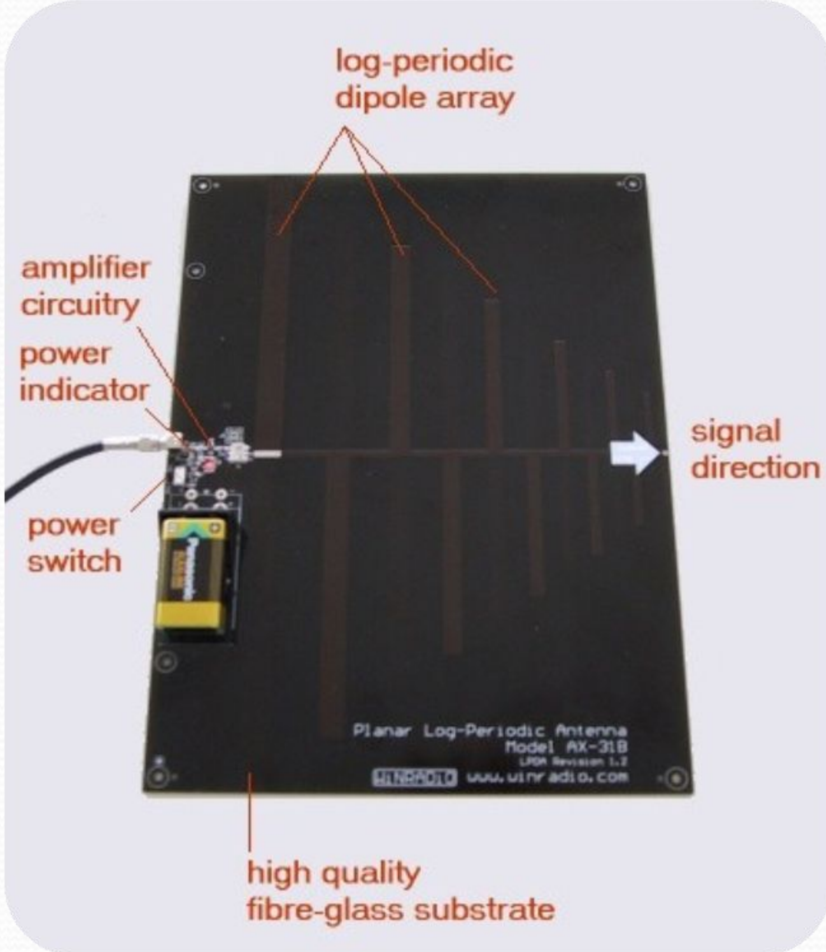
- Input impedance of folded dipole is four times higher than that of straight dipole.
- Typically the input impedance of half wavelength folded dipole antenna is 288 ohm.
- Bandwidth of folded dipole is higher than that of straight dipole.

Biconical Antenna

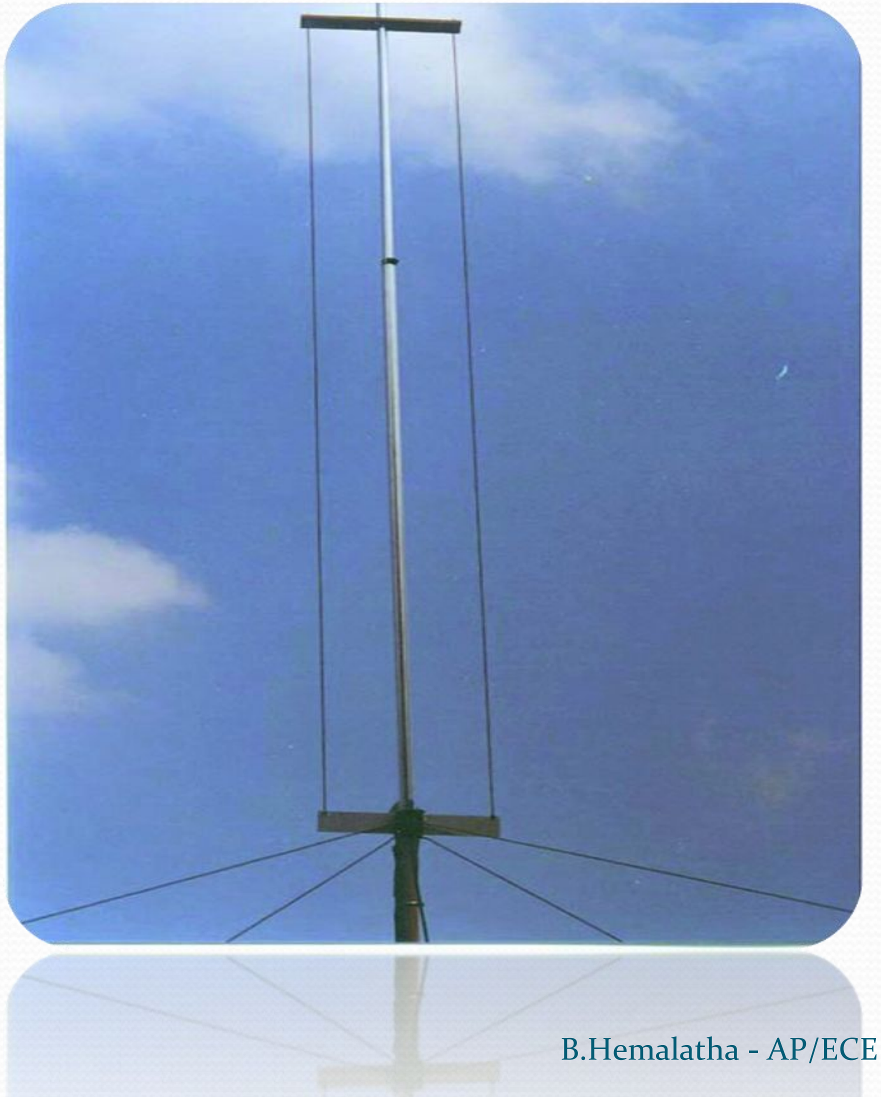
- Types of Biconical
  - Infinite Biconical
  - Finite Biconical
  - Discone

Log Periodic Antenna

- The antenna is ideally suited for reception of VHF/UHF point-to-point communication where its directional characteristics can significantly improve rejection of interfering signals.
- In professional applications, this antenna is ideally suited for EMC pre-testing, surveillance and monitoring.
- The antenna covers a frequency range of 230 to 1600 MHz (a much wider frequency range can be received with reduced gain).



Sleeve Antenna

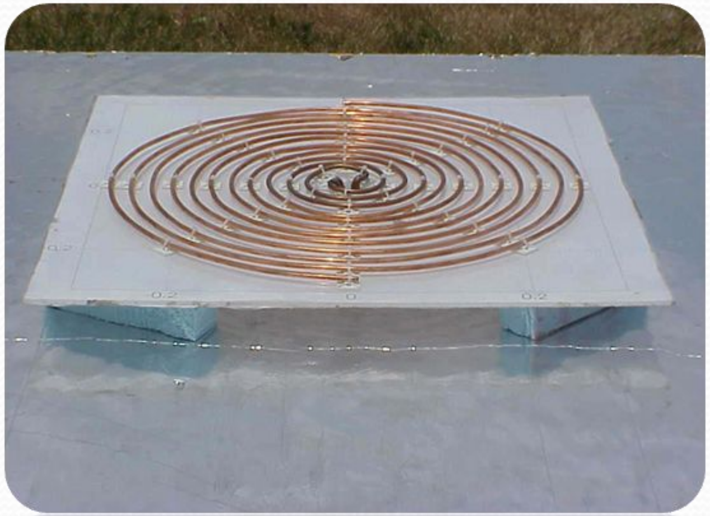


The sleeve antenna is used primarily as a receiving antenna. It is a broadband, vertically polarized, omnidirectional antenna.

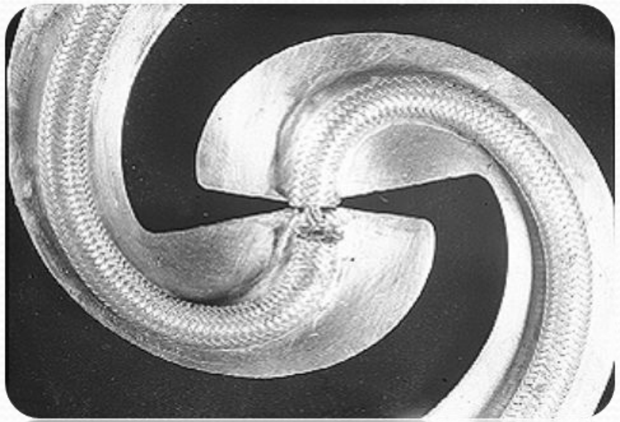
Its primary uses are in broadcast, ship-to-shore, and ground-to-air communications.

Although originally developed for shore stations, there is a modified version for shipboard use.

Spiral Antenna

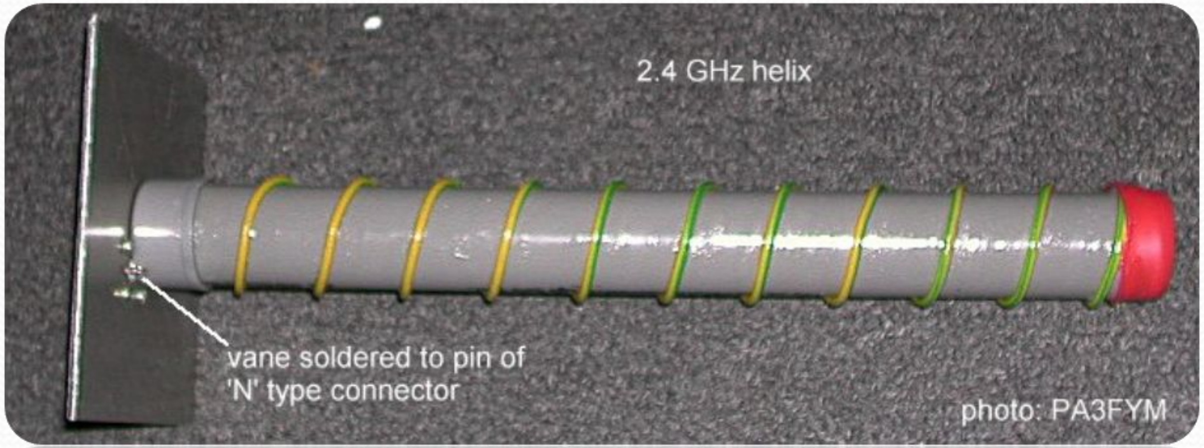


- The spiral antenna is used primarily as a receiving antenna
- Vertically polarized
- Frequency Independent
  - Designed to minimize finite lengths and maximize angular dependence



Helical Antenna

- Directional
- Circularly Polarized
  - Polarization changes with time
- Both high gain and wide band



Geometry

D= diameter of helix

C= circumference of helix

Lo= length of one turn = $\sqrt{C^2 + S^2}$

α= pitch angle = $\tan^{-1}(\frac{S}{\pi D})$

S= spacing between turns

N= number of turns

Lw= length of helix

d= diameter of conductor

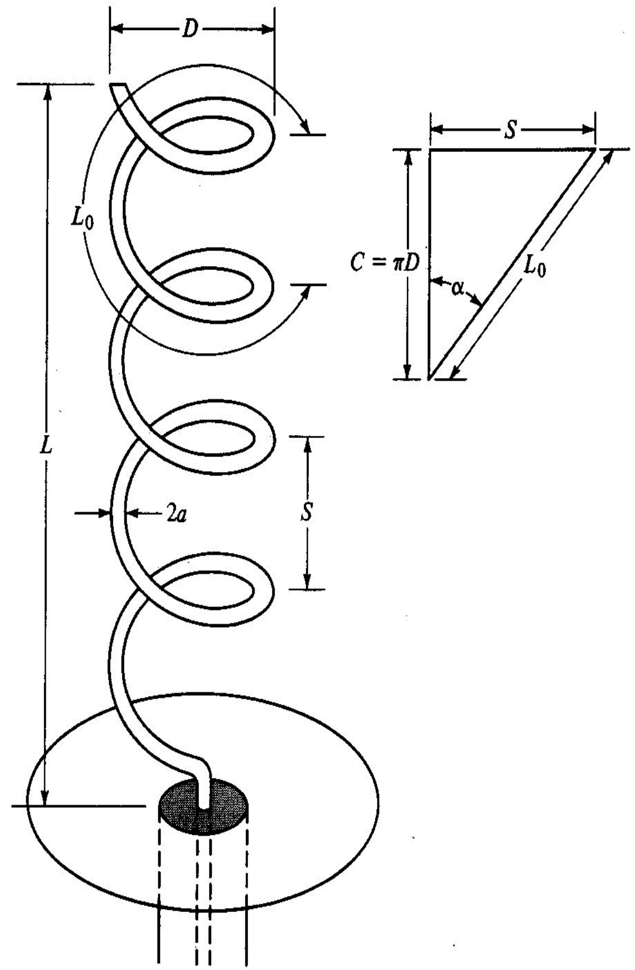
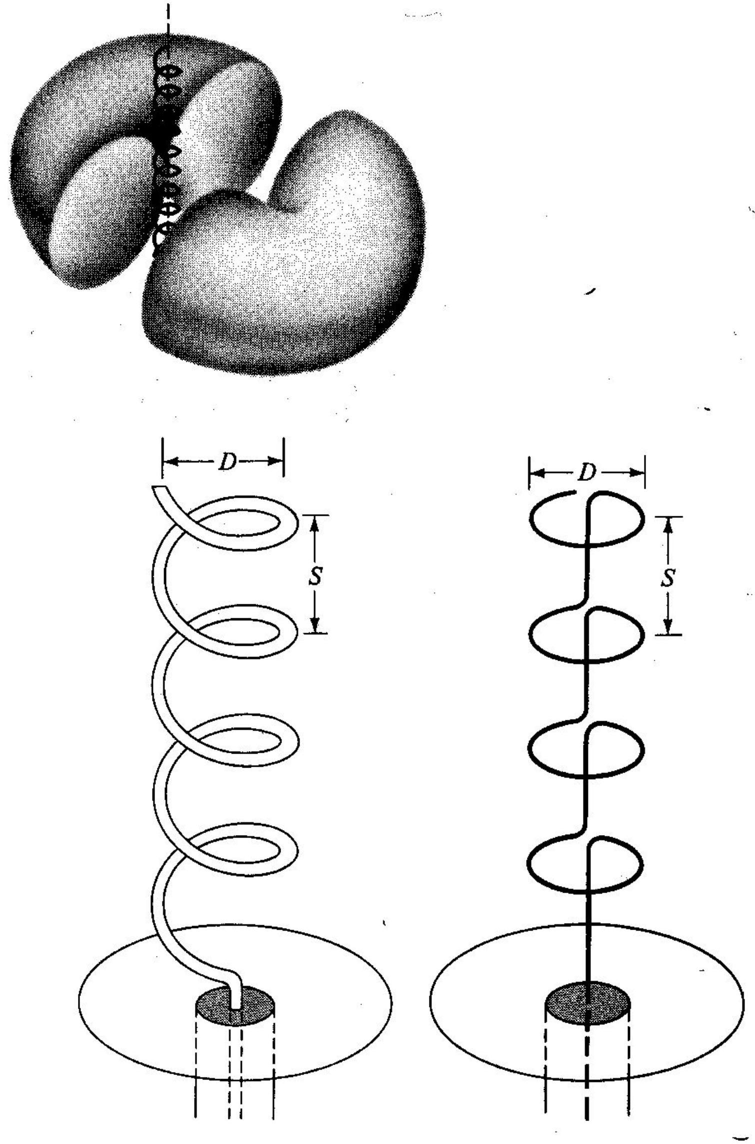


Figure 9.9 Helical antenna with ground plane.

Normal Mode

- Radiation pattern similar to linear dipole
- The dimensions of the helix are small compared to the wavelength
- Narrow in bandwidth
- Radiation efficiency is small
- Rarely used



(a) Normal mode (b) Equivalent

Axial Mode

- Circular Polarization
  - ¾<C/λ<4/3
  - C/λ=1:near optimum
  - S= λ/4
- Half-Power Beam width: 50 x 50 degrees

$$\frac{52\lambda^{3/2}}{C\sqrt{NS}}$$

- Directivity:

$$15N\frac{C^2S}{\lambda^3}$$

- Typical Gain: 10dB
- Bandwidth: 52%
- Frequency limit: 100MHZ to 3GHz

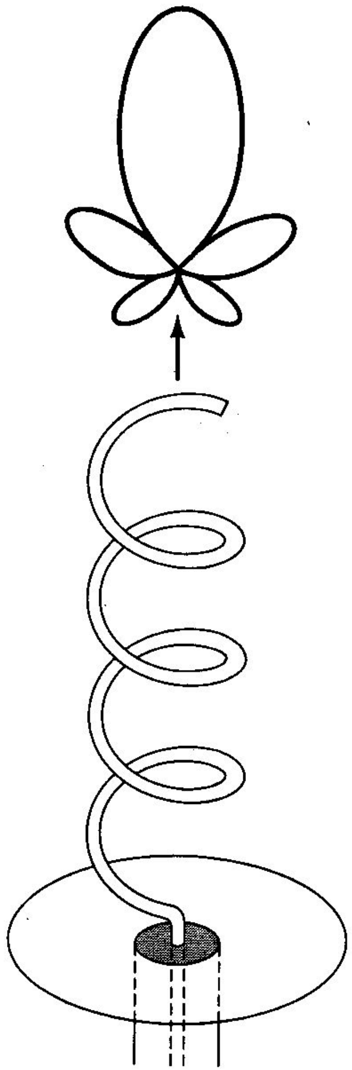
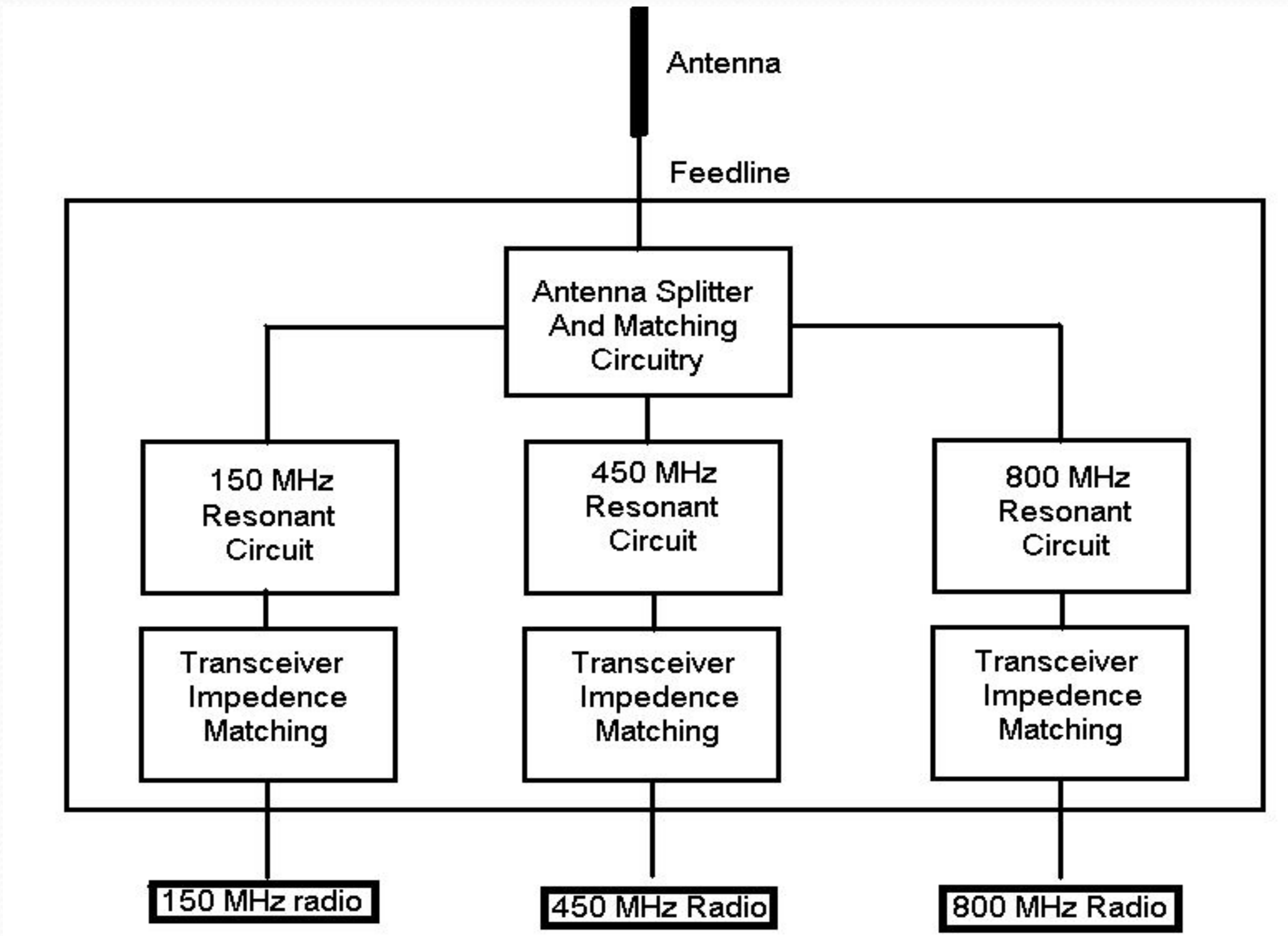


Figure 9.11 Axial (endfire) mode of helix.

Helix Applications

- Space Telemetry Applications of satellites, space probes, and ballistic missiles
  - Signals have undergone Faraday rotation
- Directional applications

Adaptation of Single Antenna for Multi-band Use.



Antenna Characterization

- antennas generate EM field pattern
- not always possible to model mathematically
- difficult to account for obstacles
- antennas are studied in EM **isolated rooms** to extract key performance characteristics

antenna design & relative **signal intensity** determines relative field pattern

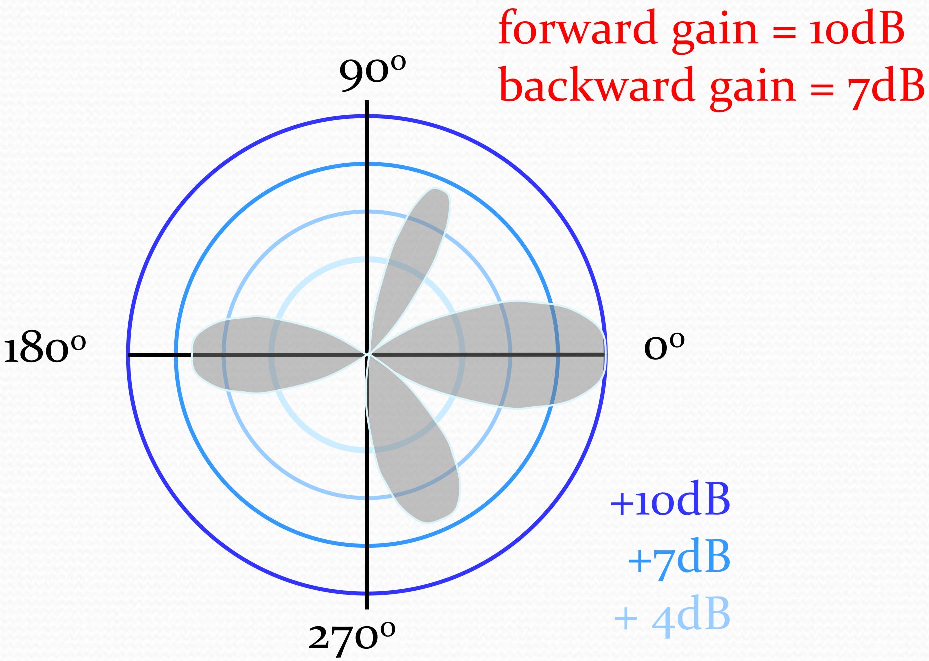
absolute value of **signal intensity** varies for given antenna design

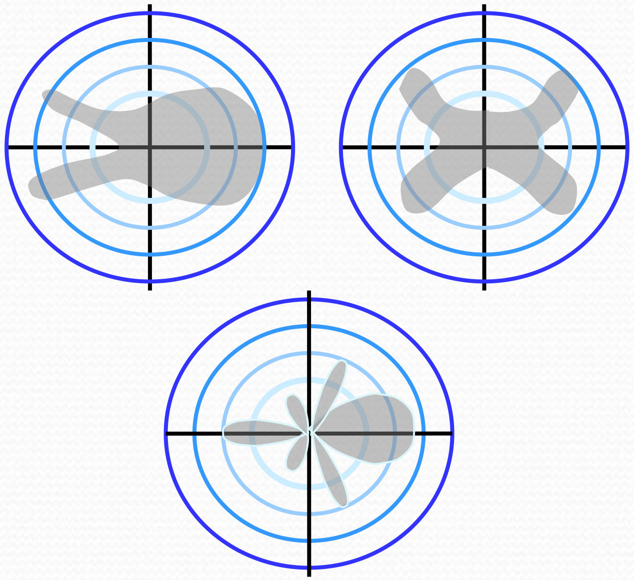
- at the transmitter this is related to power applied at transmitter

- at the receiver this is related to power in surrounding space

Polar Plot of relative signal strength of radiated field

- shows how field strength is shaped
- generally 0º aligned with major physical axis of antenna
- most plots are relative scale (dB)
  - maximum signal strength location is 0 dB reference
  - closer to center represents weaker signals





radiated field shaping ≈ lens & visible light

- application determines required direction & focus of signal
- antenna characteristics

  (i) radiation field pattern

  (ii) gain

  (iii) lobes, beamwidth, nulls

  (iv) directivity

(i) antenna field pattern = general shape of signal intensity in *far-field*

far-field measurements measured many wavelengths away from antenna

near-field measurement involves complex interactions of decaying electrical and magnetic fields - many details of antenna construction

Measuring Antenna Field Pattern

field strength meter used to measure field pattern

- indicates amplitude of received signal
- calibrated to receiving antenna
- relationship between meter and receive antenna known

  measured strength in *u*V/meter

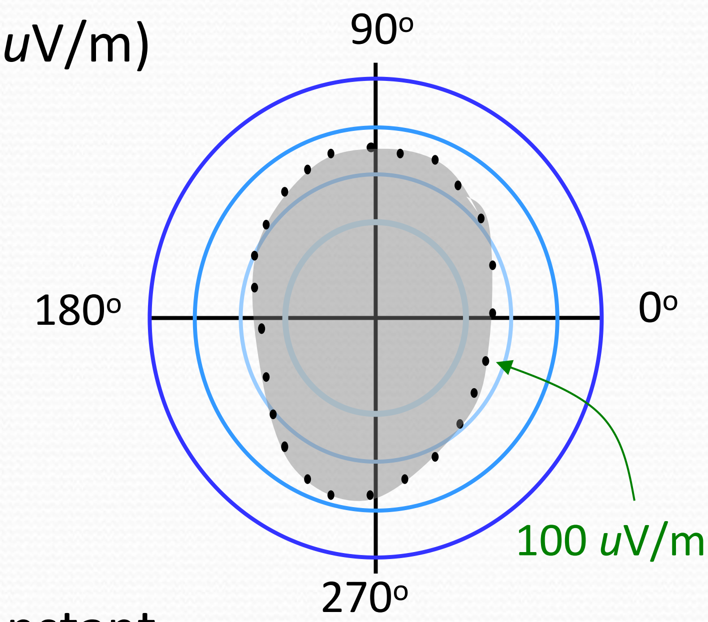
  received power is in *u*W/meter

- directly indicates EM field strength

Determination of overall Antenna Field Pattern

form Radiation Polar Plot Pattern

- use nominal field strength value (e.g. 100*u*V/m)
- measure points for 360º around antenna
- record distance & angle from antenna
- connect points of equal field strength



Practically

- distance between meter & antenna kept constant
- antenna is rotated
- plot of field strength versus angle is made

Why Shape the Antenna Field Pattern ?

- transmit antennas: produce higher effective power in **direction** of intended receiver
- receive antennas: concentrate **energy collecting** ability in direction of transmitter
  - **reduced noise** levels - receiver only picks up intended signal
- avoid unwanted receivers (multiple access interference = **MAI**):
  - security
  - multi-access systems
- **locate** target direction & distance – e.g. radar

not always necessary to shape field pattern, standard broadcast is often omnidirectional - 360^{o}

Antenna Gain

Gain is Measured Specific to a **Reference Antenna**

- **isotropic antenna** often used - *gain over isotropic*
  - isotropic antenna – radiates power ideally in all directions
  - gain measured in dBi
  - test antenna's field strength relative to reference isotropic antenna
  - at same *power, distance*, and *angle*
  - isotropic antenna cannot be practically realized

- **½ wave dipole** often used as reference antenna
  - easy to build
  - simple field pattern

Antenna Gain ≠ Amplifier Gain

- antenna power output = power input – transmission line loss
- antenna shapes radiated field pattern
- **power measured** at a point is greater/less than that using **reference antenna**
- **total power output doesn't increase**
- power output in given direction increases/decreases relative to reference antenna

e.g.

a lamp is similar to an isotropic antenna

a lens is similar to a directional antenna

- provides a gain/loss of visible light in a specific direction
- doesn't change actual power radiated by lamp

- **transmit antenna** with 6dB gain in specific direction over isotropic antenna → 4× transmit power in that direction
- **receive antenna** with 3dB gain is some direction receives 2× as much power than reference antenna

Antenna Gain

often a cost effective means to

(i) increase effective transmit power

(ii) effectively improve receiver sensitivity

may be only technically viable means

- more power may not be available (batteries)
- front end noise determines maximum receiver sensitivity

Rotational Antennas can vary direction of antenna gain

Directional Antennas focus antenna gain in primary direction

Beamwidth, Lobes & Nulls

Lobe: area of high signal strength

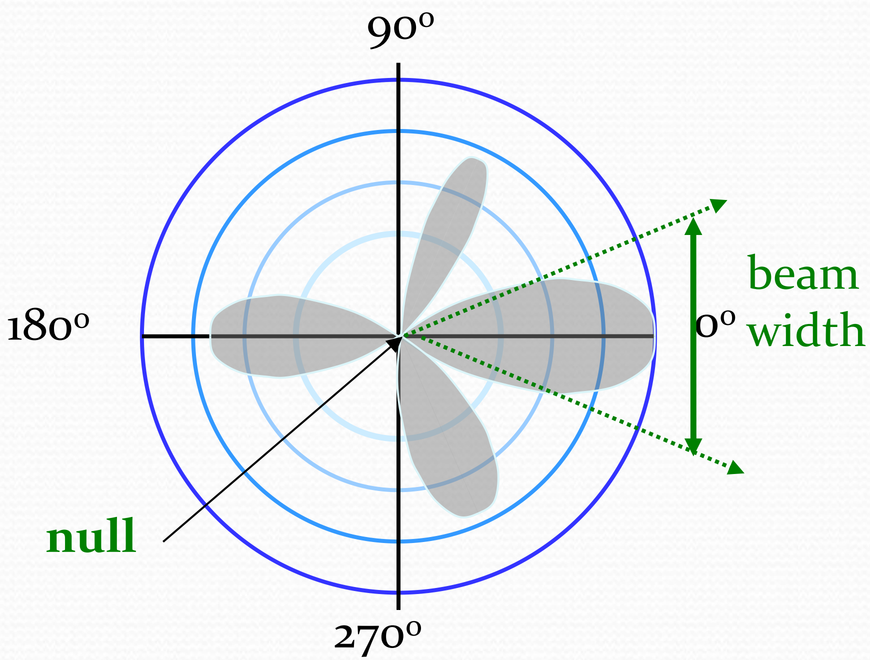
- main lobe
- secondary lobes

Nulls: area of very low signal strength

Beamwidth:

Total angle where relative signal power is 3dB below peak value of main lobe

- can range from 1° to 360°



Beamwidth & Lobes indicate sharpness of pattern focus

Center Frequency = optimum operating frequency

Antenna Bandwidth ≡ -3dB points of antenna performance

Bandwidth Ratio: Bandwidth/Center Frequency

e.g. f_c = 100MHz with 10MHz bandwidth

- radiated power at 95MHz & 105MHz = ½ radiated power at f_c
- bandwidth ratio = 10/100 = 10%

Antenna Design Basics

Main Trade-offs for Antenna Design

- directivity & beam width
- acceptable lobes
- maximum gain
- bandwidth
- radiation angle

Bandwidth Issues

High Bandwidth Antennas tend to have less gain than narrowband antennas

Narrowband Receive Antenna reduces interference from adjacent signals & reduce received noise power

Antenna Dimensions

- operating frequencies determine physical size of antenna elements
- design often uses λ as a variable (*e.g. 1.5 λ length, 0.25 λ spacing*)

Testing & Adjusting Transmitter → use antenna's electrical load

- Testing required for
  - proper modulation
  - amplifier operation
  - frequency accuracy
- using actual antenna may cause significant interference
- **dummy antenna used** for transmitter design (not antenna design)
  - same impedance & electrical characteristics
  - dissipates energy vs radiate energy
  - isolates antenna from problem of testing transmitter

Testing Receiver

- test & adjust receiver and transmission line **without antenna**
- use single known signal from RF generator
- follow on test with several signals present
- **verify receiver** operation first → then connect antenna to **verify antenna** operation

Polarization

- EM field has specific orientation of E-field & M field
- Polarization Direction determined by antenna & physical orientation
- Classification of E-field polarization
  - **horizontal polarization** : E-field parallel to horizon
  - **vertical polarization:** E-field vertical to horizon
  - **circular polarization**: constantly rotating

Transmit & Receive Antenna

- must have same Polarization for maximum signal energy induction
- if polarizations aren't same → E-field of radiated signal will try to induce E-field into wire ⊥ to correct orientation

- theoretically no induced voltage

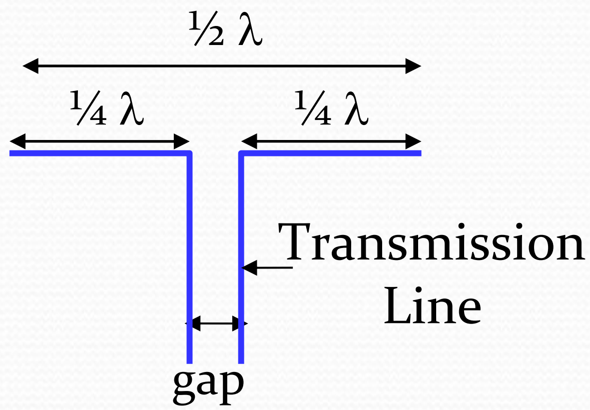
practically – small amount of induced voltage

Circular Polarization

- compatible with any polarization field from horizontal to vertical
- maximum gain is 3dB less than correctly oriented horizontal or vertically polarized antenna

Antenna Fundamentals

Dipole Antennas (Hertz): simple, old, widely used
- root of many advance antennas

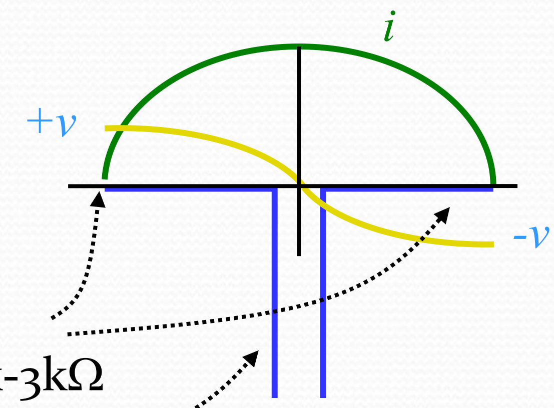


- consists of 2 spread conductors of 2 wire transmission lines
- each conductor is ¼ λ in length
- total span = ½ λ + small center gap

Distinct voltage & current patterns

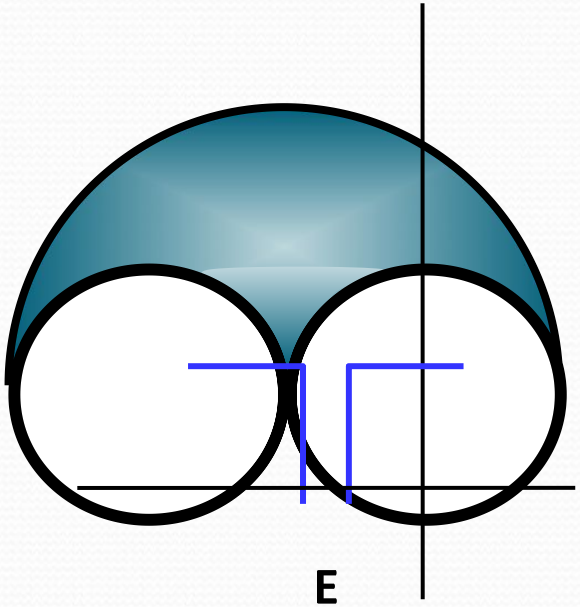
driven by *transmission line* at midpoint

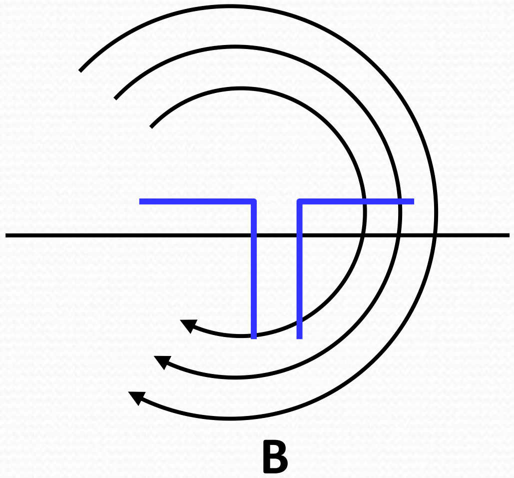
- i = 0 at end, maximum at midpoint
- v = 0 at midpoint, $\pm v_{max}$ at ends
- purely resistive impedance = 73Ω
- easily matched to many transmission lines



E-field (**E**) & M-field (**B**) used to determine radiation pattern

- **E** goes through antenna ends & spreads out in increasing loops
- **B** is a series of concentric circles centered at midpoint gap



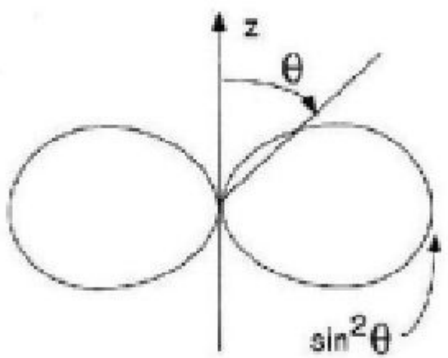


3-dimensional field pattern is **donut shaped**

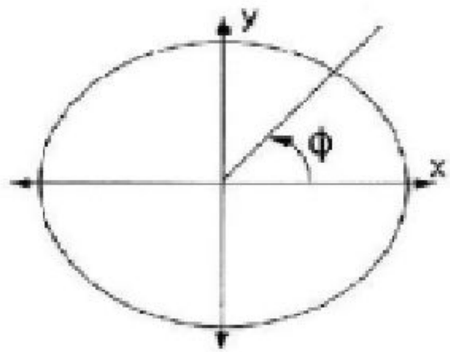
antenna is shaft through donut center

radiation pattern determined by taking slice of donut

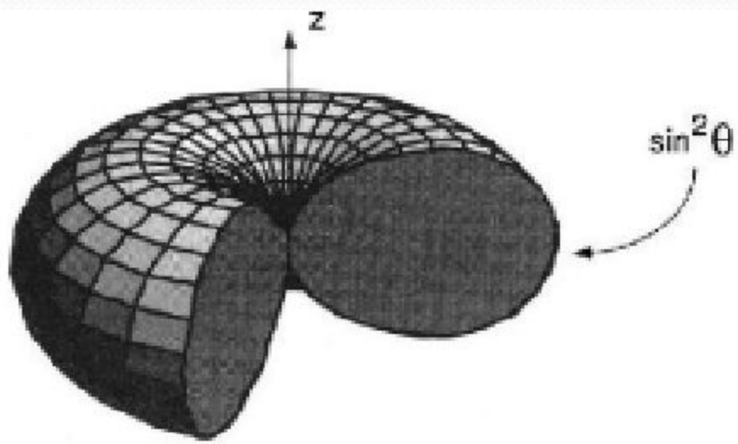
- if antenna is horizontal → slice reveals figure 8
- maximum radiation is broadside to antenna’s arms



Elevation Pattern



Azimuth Pattern



Polar Radiation Pattern

½λ dipole performance – isotropic reference antenna

- in free space → beamwidth = 78°
- maximum gain = 2.1dB
- dipole often used as reference antenna
  - feed same signal power through ½ λ dipole & test antenna
  - compare field strength in all directions

Actual Construction

(i) propagation velocity in wire < propagation velocity in air

(ii) fields have **'fringe effects'** at end of antenna arms

- affected by capacitance of antenna elements

1st estimate: make real length 5% less than ideal – otherwise introduce reactive parameter

Useful Bandwidth: 5%-15% of f_c

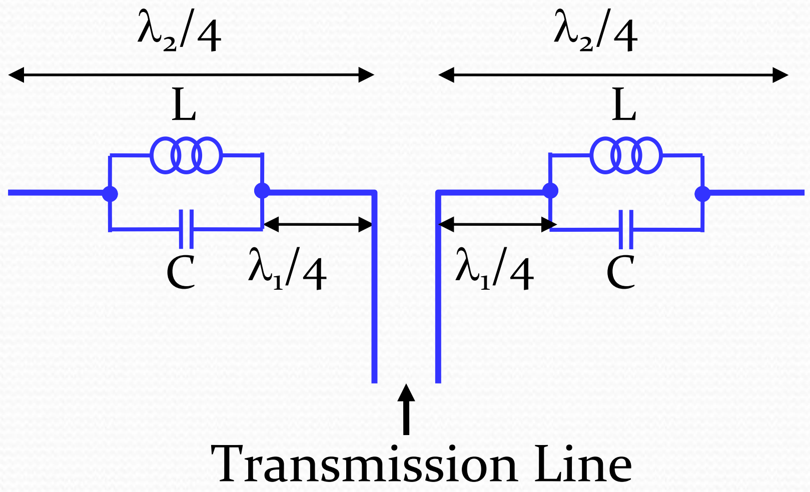
- major factor for determining bandwidth is diameter of conductor
- smaller diameter → narrow bandwidth

Multi-Band Dipole Antennas

use 1 antenna → support several widely separated frequency bands
e.g. *HAM Radio - 3.75MHz-29MHz*

Traps: *L,C* elements inserted into dipole arms

- arms appear to have different lengths at different frequencies
- traps must be suitable for outdoor use
- 2ndry affects of trap impact effective dipole arm length-adjustable
- not useful over 30MHz

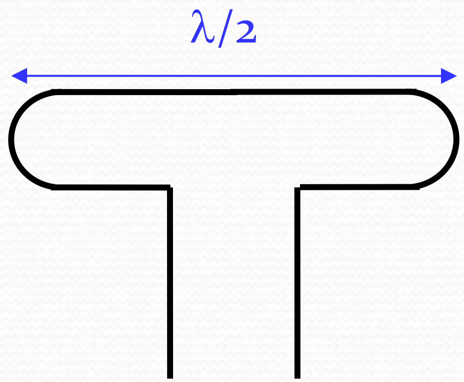


Transmit Receive Switches

- allows use of single antenna for transmit & receive
- alternately connects antenna to transmitter & receiver
- high transmit power must be isolated from high gain receiver
- isolation measured in dB

e.g. 100dB isolation→ 10W transmit signal ≈ 10nW receive signal

Folded Dipole Antenna



- basic ½λ dipole folded to form complete circuit

- core to many advanced antennas

- mechanically more rugged than dipole

- 10% more bandwidth than dipole

- input impedance ≈ 292 Ω

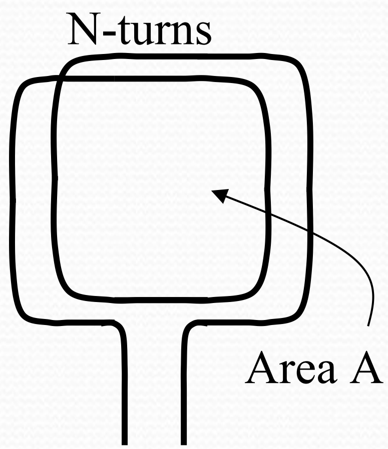
- close match to std 300Ω twin lead wire transmission line

- use of different diameter upper & lower arms → allows variable impedance

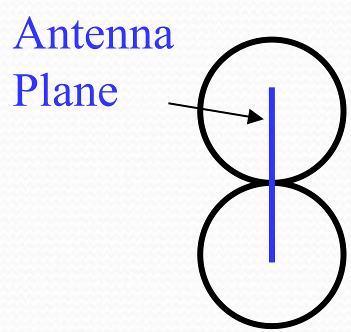
Loop & Patch Antenna – wire bent into loops

Patch Antenna: rectangular conducting area with || ground plane

$$V = k(2\pi f)BAN$$



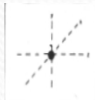
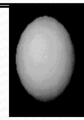
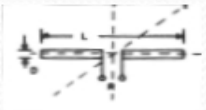
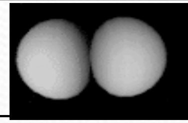
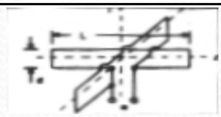
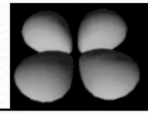
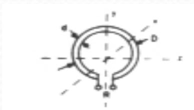
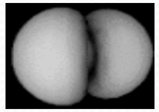
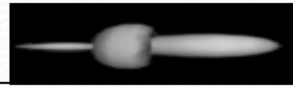
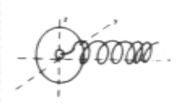
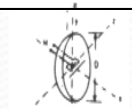
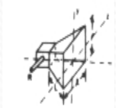
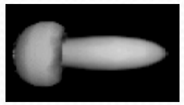
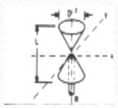
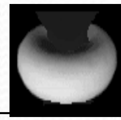
- V = maximum voltage induced in receiver by EM field
- B = magnetic field strength flux of EM field
- A = area of loop
- N = number of turns
- f = signal frequency
- k = physical proportionality factor



Radiation Pattern

- maximum $\perp$ to center axis through loop
- very low broadside to the loop
- useful for direction finding
  - rotate loop until signal null (minimum) observed
  - transmitter is on either side of loop
  - intersection with 2nd reading pinpoints transmitter

- Loop & Patch Antennas are easy to embed in a product (e.g. pager)
- Broadband antenna - 500k-1600k Hz bandwidth
- Not as efficient as larger antennas

Name	Shape	Gain (over isotropic)	Beamwidth - 3 dB	Radiation Pattern
Isotropic		0 dB	360	
Dipole		2.14 dB	55	
Turnstile		-0.86 dB	50	
Full Wave Loop		3.14 dB	200	
Yagi		7.14 dB	25	
Helical		10.1 dB	30	
Parabolic Dipole		14.7 dB	20	
Horn		15 dB	15	
Biconical Horn		14 dB	360x200	

Radiation Pattern Measurements (1)

- Measured antenna in receiving mode
  - The antenna is rotated (or the radiowave source is moved around)
  - The power received (output voltage) is registered vs. the direction angle (azimuth, elevation)
- Measured antenna in transmitting mode
  - The antenna is rotated (or the field-strength meter is moved around)
  - The field-strength is registered vs. the direction angle (azimuth, elevation)

Radiation Pattern Measurements (2)

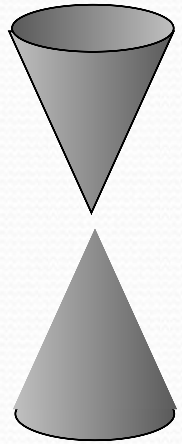
- Laboratory
  - Special test site
    - Open field
    - Anechoic chamber
    - Near-field / Far field calculation
    - Scaling
- Field
  - In-situ measurements
    - Measuring instruments in car, balloon, aeroplane, or helicopter
    - Actual distance / standard distance problem
    - Environmental effects

Electric Field Measurement

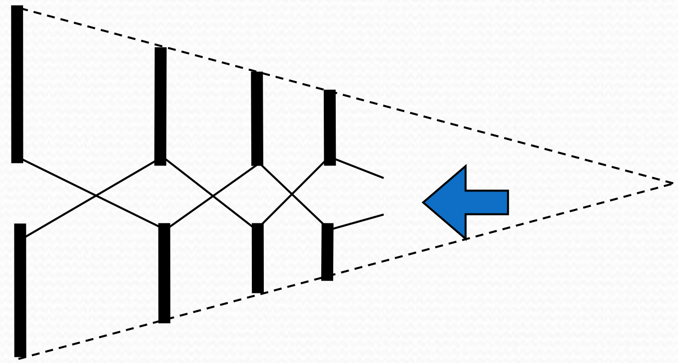
- Dipole antenna
- Balance matching
- Impedance matching

Wideband Antennas

- Impedance and radiation pattern of antenna are frequency dependent

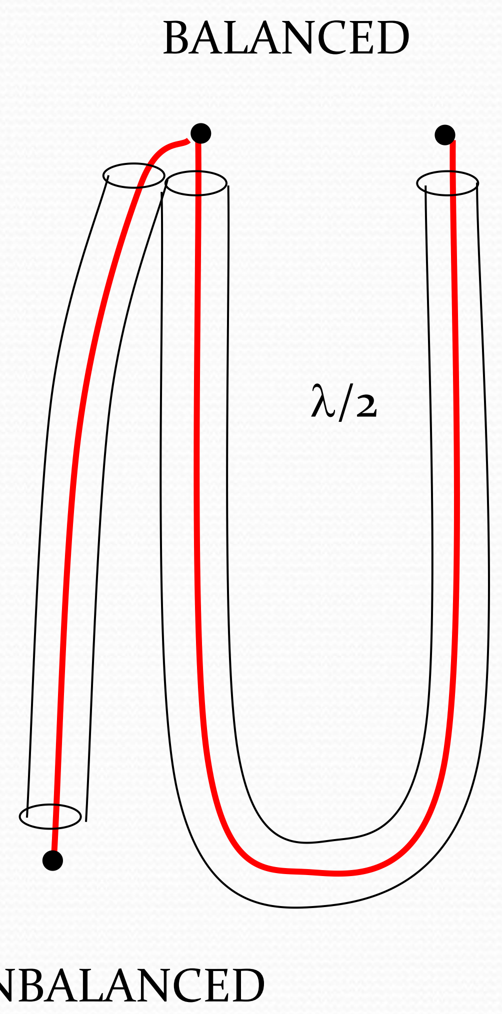


- Wideband antennas
  - Conical antennas
  - Equi-angular antennas
  - Log-spiral antennas
  - Log-periodic antennas

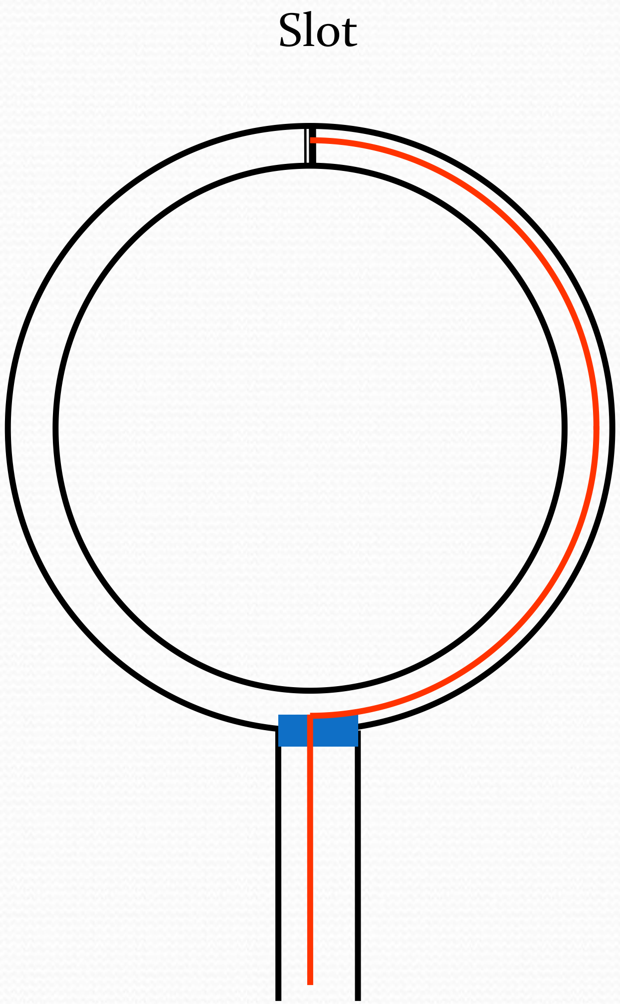


Impedance Matching

- For maximum power transfer the load impedance must match the source impedance:
  - $R_{LOAD} = R_{SOURCE}$
  - $X_{LOAD} = -X_{SOURCE}$
- Transmission line must terminate in its characteristic impedance
- The balanced/ unbalanced mode-continuity must be assured or a transformer (balun) must be used



Magnetic Field Measurement



- Loop antenna
- Screen against electric component

Gain Measurements: 2 Antennas

- Reciprocity method
  - 2 identical antennas are used: one as the transmitting antenna and another as receiving antenna
  - The ratio of the power received to power transmitted is measured

$$P_R = P_T G_T G_R \left(\frac{\lambda}{4\pi r} \right)^2$$

$$G_T = G_R = G$$

$$G = \sqrt{\frac{P_R}{P_T} \left(\frac{4\pi r}{\lambda} \right)}$$

Gain Measurements: 3 Antennas

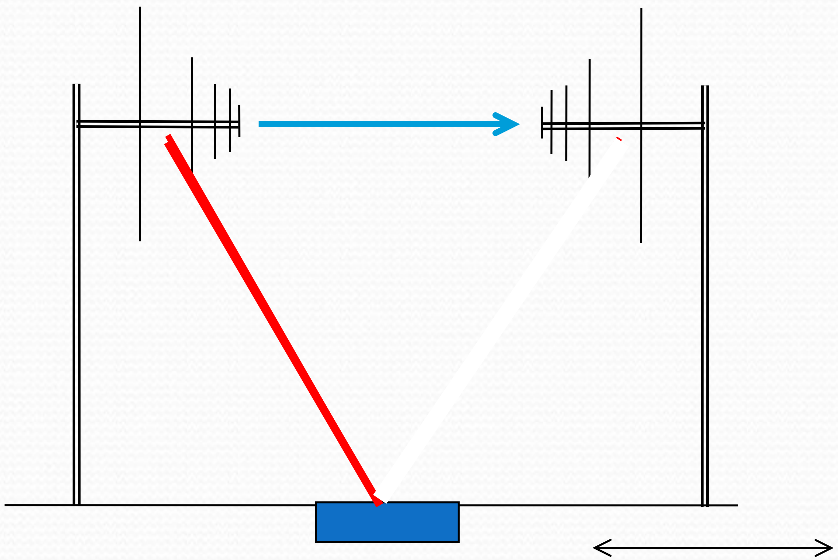
- The 3-antenna method can be used to calibrate 3 arbitrary antennas.
- 3 measurements are made, giving 3 equations with 3 unknown gains
- It is the only method applicable to active antennas that cannot be used in transmit mode.

$$P_{12} = P_T G_1 G_2 \left(\frac{\lambda}{4\pi r} \right)^2$$

$$P_{23} = P_T G_2 G_3 \left(\frac{\lambda}{4\pi r} \right)^2$$

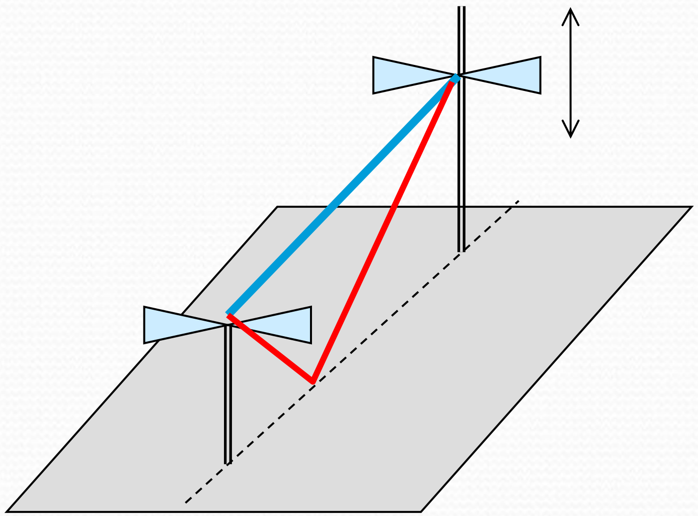
$$P_{13} = P_T G_1 G_3 \left(\frac{\lambda}{4\pi r} \right)^2$$

Calibrating Test Antennas (1)



- Simulation of free-space conditions
  - Removing the reflected ray by using absorbers
  - Exploiting directivity (radiation nulls)
  - Practical with vertical polarization
  - Does not require anechoic chamber

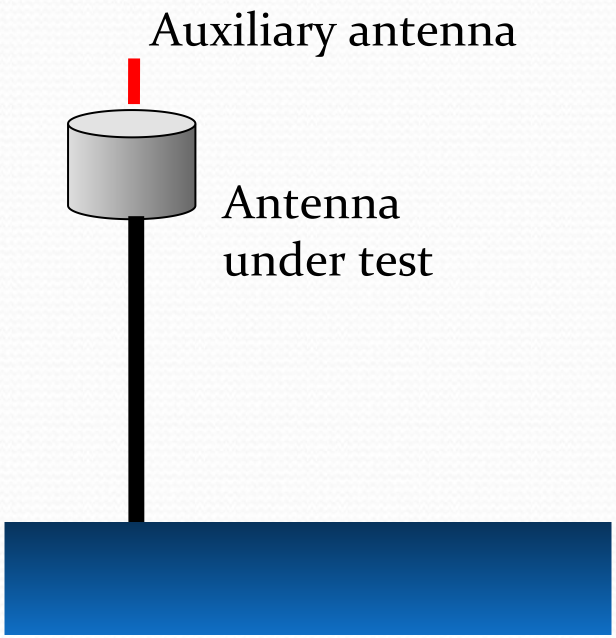
Calibrating Test Antennas (2)



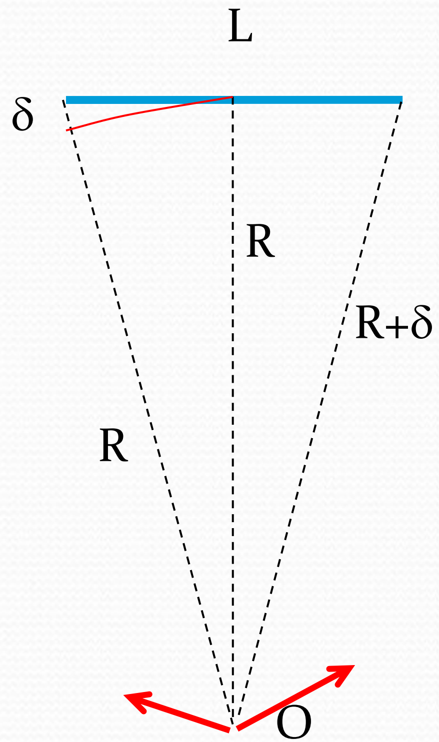
- Exploiting reflection
  - Using conducting surface
  - Adjusting antenna height to receive maximum
  - Practical with horizontal polarization
  - Does not require anechoic chamber

Measurements in the Field

- Relative (comparative) measurements using an auxiliary antenna of known radiation pattern eliminate the distance dependence



Far-Field Conditions



1. $R >> (\lambda/2\pi)$
2. $R >> 2L^2 / \lambda$

$\delta << \lambda/16$ (22,5 deg. instead of 0 deg.)

$(R+\delta)^2 = R^2 + (L/2)^2$

$\underline{R^2} + 2R\delta + \delta^2 = \underline{R^2} + (L/2)^2$

$2R\delta + \underline{\delta^2} = (L/2)^2$

$R \sim (L/2)^2 / (2\delta) = L^2 / 8\delta$

$R >> (L^2/8) * (16/\lambda)$

Important when dealing with radiation nulls

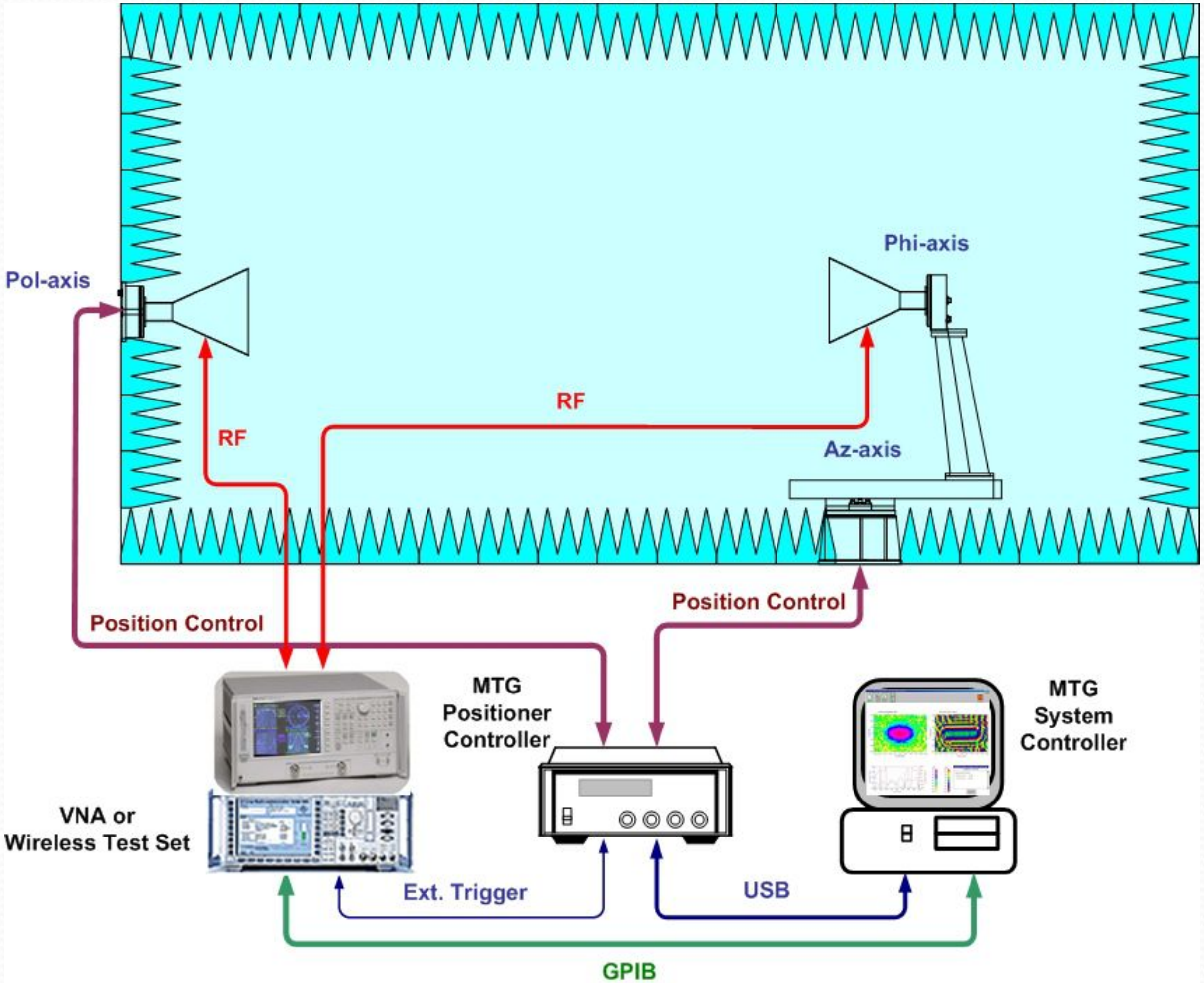
Example

- Antenna diameter = 2 m

1. 300 MHz (λ = 1 m)
   - $\lambda/2\pi$ = 1/ 6.28 ~ 0.16 m
   - $2L^2/\lambda$ = 8 / 1 = 8 m

2. 3000 MHz (λ = 0.1 m)
   - $\lambda/2\pi$ = 0.1/6.28 ~ 0.016 m
   - $2L^2/\lambda$ = 8 / 0.1 = 80 m

ANECHOIC CHAMPERMEASUREMENT



2. OTA Performance Test

* **CTIA : “Test Plan for Mobile Station Over the Air Performance”**
  - March 2003, Revision 2.0
  - Method of Measurement for Radiated RF Power
    and Receiver Performance

* **Contents**
  - Test Site Characteristics and Quiet Zone Accuracy – Requirements
    and Test Method and Procedure
  - Substitution Part : Measurement for Path Loss Calibration
  - Radiated Power Measurement
  - Receiver Performance(Sensitivity) Measurement
  - Measurement Uncertainty Analysis

3. Anechoic Chamber

*** CTIA's Minimum Requirement**

- Quiet Zone Size : Sphere of 300mm Diameter for Measurement involving Head Phantom

- Minimum Test Length : 1.19m

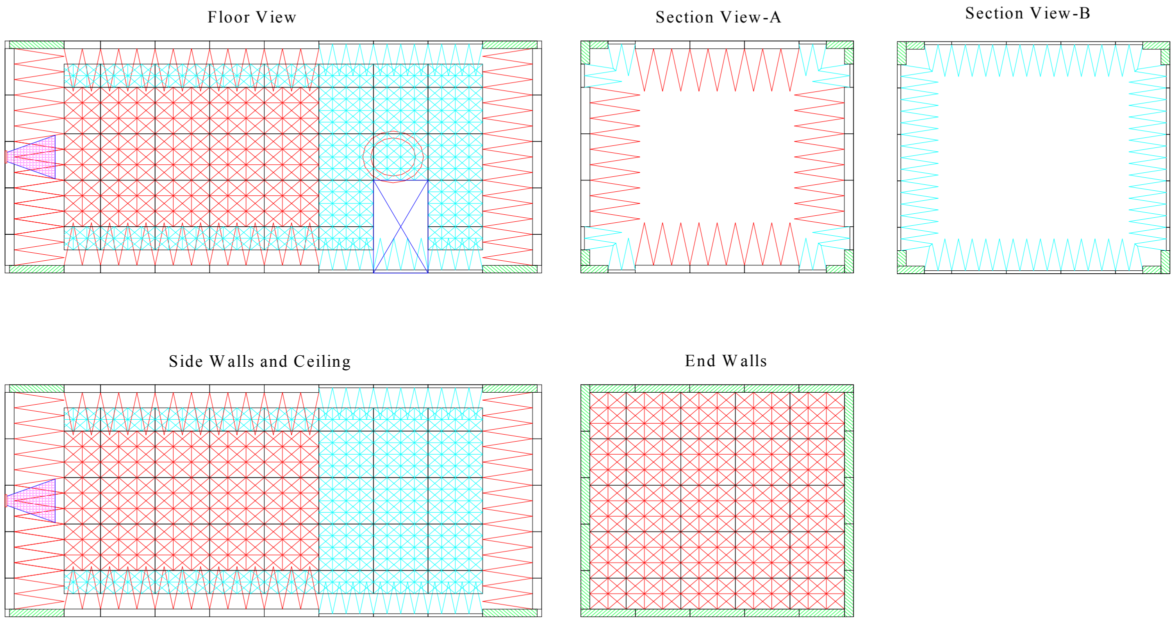
- +/- 1.0dB Ripple to Guarantee the Uncertainty Level of 2.0dB including EUT Positioner

3. Anechoic Chamber

* Specifications

Frequency	QZ Diameter *	Transmit Antenna Gain	Receive Antenna Gain	Guaranteed Q. Z. Reflectivity	Guaranteed Q. Z. Ripple
800 MHz	75 cm	6 dBi	7 dBi	-25 dB	+/- 0.49 dB
1 GHz	67 cm	9 dBi	7 dBi	-30 dB	+/- 0.28 dB
1.8 GHz	50 cm	12 dBi	7 dBi	-35 dB	+/- 0.16 dB
3 GHz	38 cm	13 dBi	7 dBi	-42 dB	+/- 0.07 dB
6 GHz	27 cm	15 dBi	7 dBi	-48 dB	+/- 0.04 dB

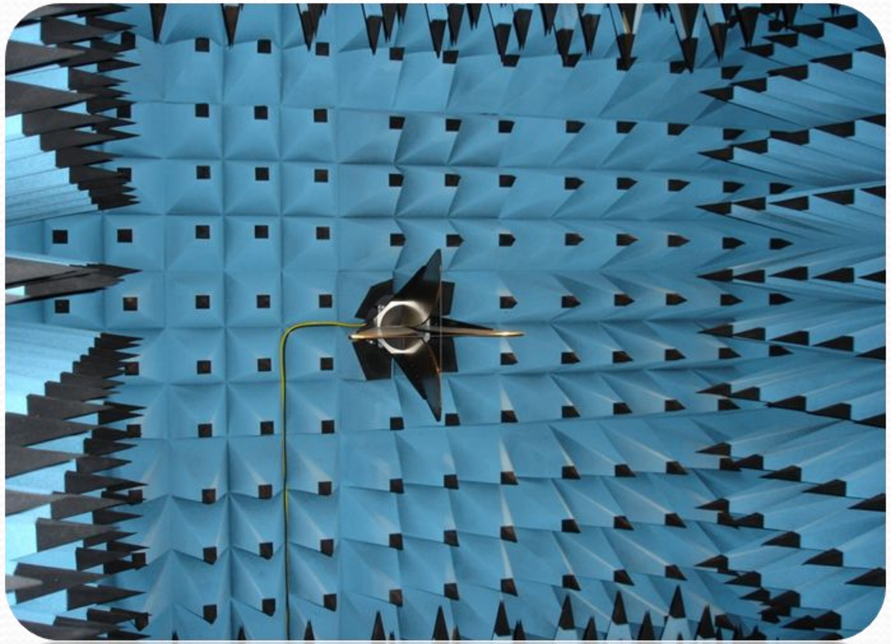
3. Anechoic Chamber

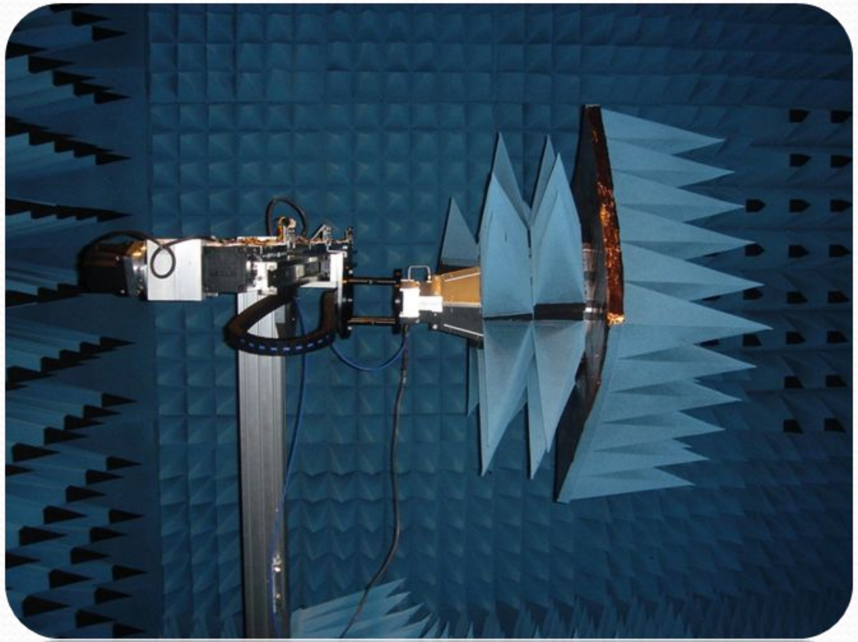


*** Absorber Layout Optimization for High Performance Chamber**

- Bidirectional Reciprocal Characteristics
- Minimize Reflection Level into Quiet Zone
- Ensure Working Space around EUT Positioner

3. Anechoic Chamber





*** Chamber Quiet Zone Test**

- Field-Probing : IEEE-STD-158-1979
- CTIA Requirement : Quiet Zone Ripple Test

4. Measurement Antenna

*** MTG's Optimized Measurement Antenna-QRH-008060**

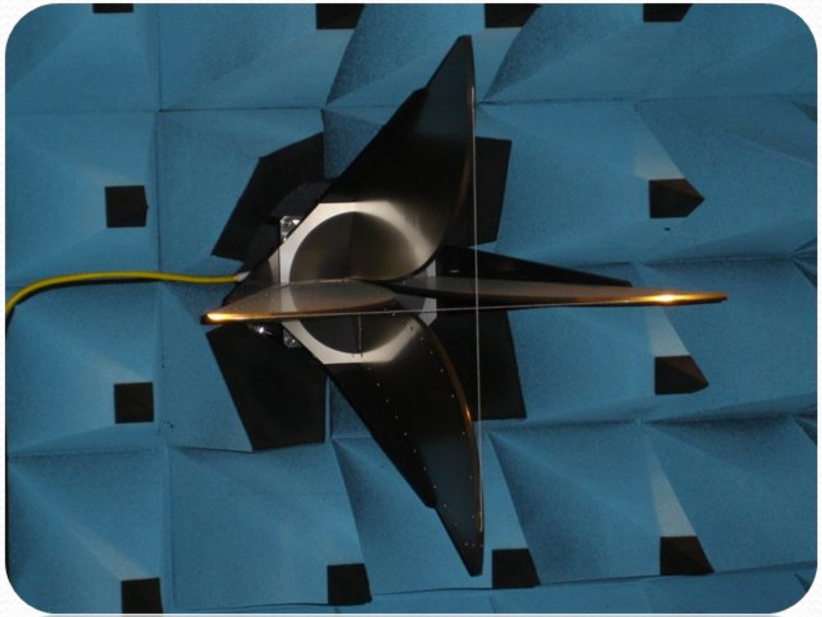
- Switchable Dual-Pol. Quad-Ridge Antenna System
- Gain is Optimized to Have Linear Slope within Frequency Band of 0.8~6.0GHz
- VSWR is Optimized to be less than 2.0 from 700MHz

*** Path Loss Compensation**

- Space Loss of Range Length 3.0m : -20.5dB/dBsm
- Isotropic Antenna Capture Area : -21.4dBsm @ 1.0GHz, -27.5dBsm @ 2.0GHz
- Cable Loss and Switch Loss from Base Station Simulator to Antenna : -3.5dB max.
- Total Loss : -45.4dB @ 1GHz, -51.5dB @ 2GHz

*** Gain is Recommended to be at Least 11.5dBi @ 2GHz**

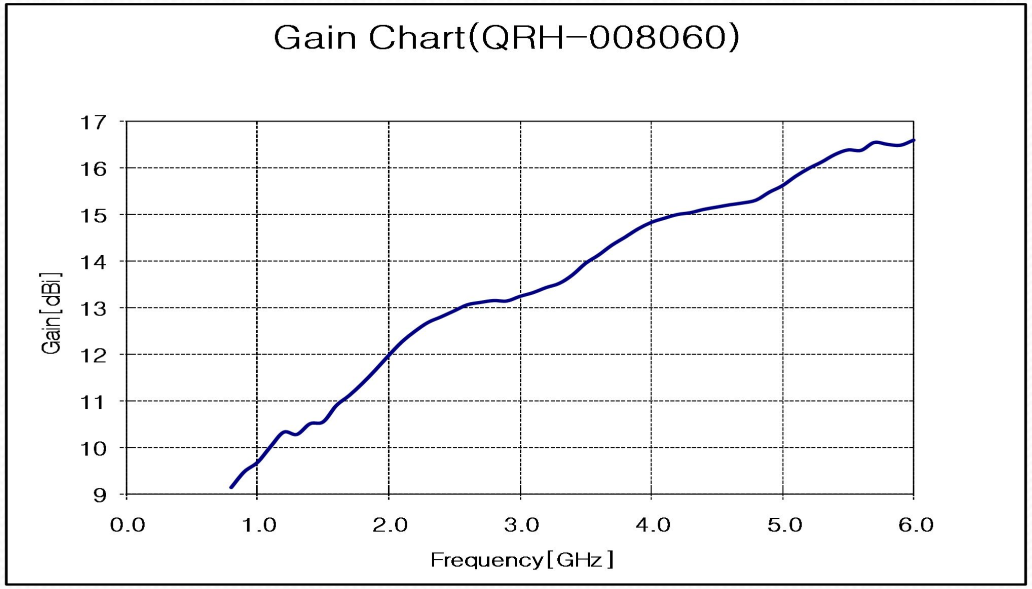
4. Measurement Antenna



*** VSWR and Isolation Characteristics**

- Less than 2.0 from 700MHz
- Isolation better than 25dB

4. Measurement Antenna



*** Optimized Gain Characteristics**

- Linear Gain Slope within 0.8~1.2GHz, 1.5~2.3GHz Bands
- Reduce Inter-Channel Differences during TX Power and Sensitivity Measurement

5. Positioners

*** High Precision Az Positioner (AP-6209)**

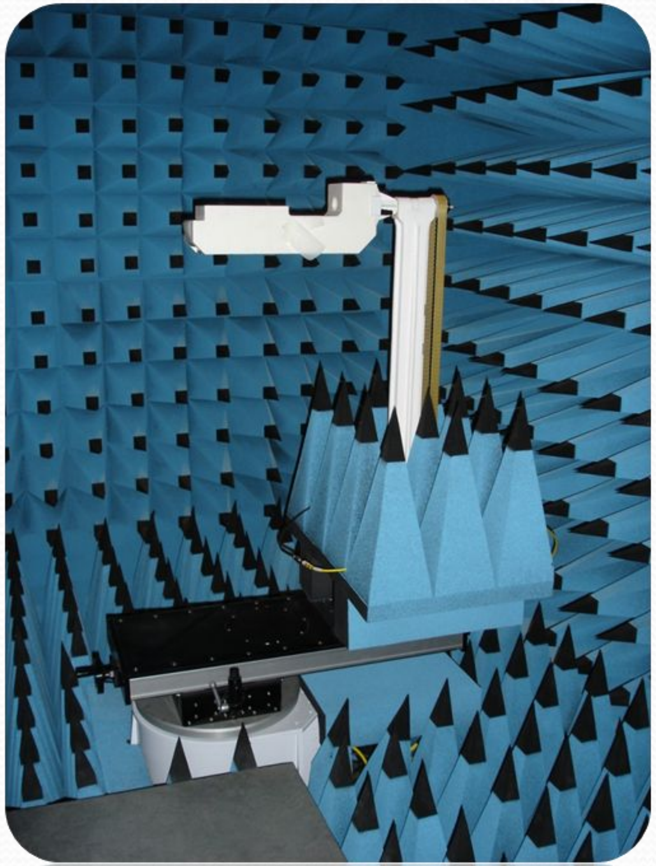
- Operating Load : 300kg
- Resolution/Accuracy : Better than 0.01deg
- Speed : up to 90deg/sec
- Rotary Joint(DC~18GHz) and Slip Ring Included

*** Transparent 3D EUT Positioner (AP-6917)**

- Satisfies CTIA's +/- 1.0dB Ripple Requirement
- Base Linear Slide for to Accommodate Various Kinds of Phantoms/Jigs
- Mast made of Low Dielectric/Low Loss Spectra
- Rotary Joint(DC~18GHz) Included
- Free Space Jig Included

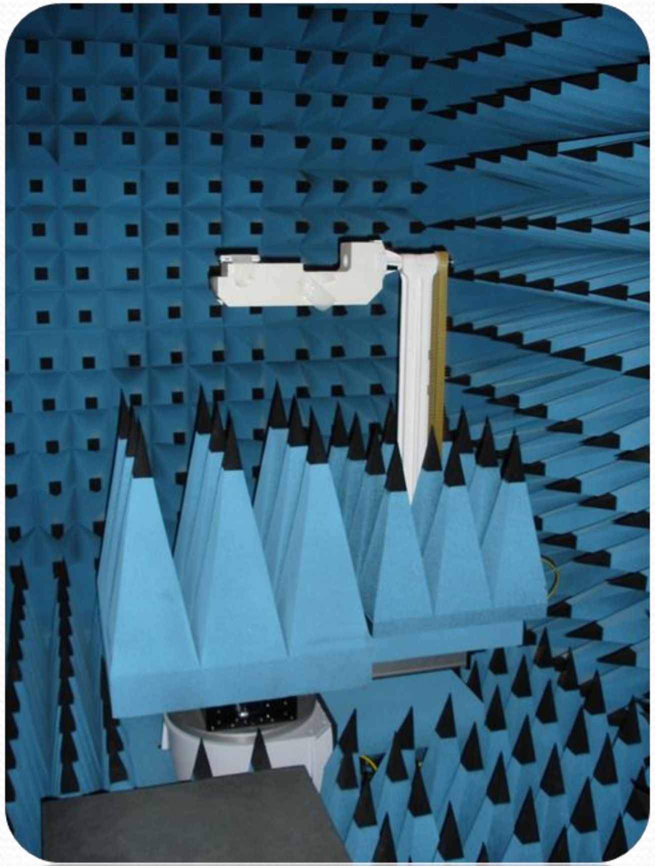
5. Positioners

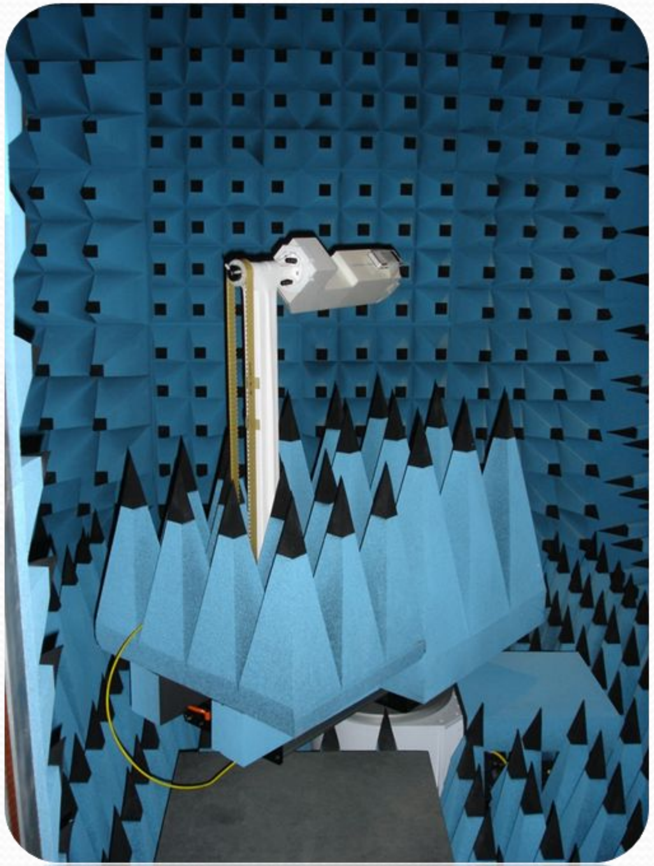
AZ Positioner (AP-6209)



(AP-6209) + (AP-6917)

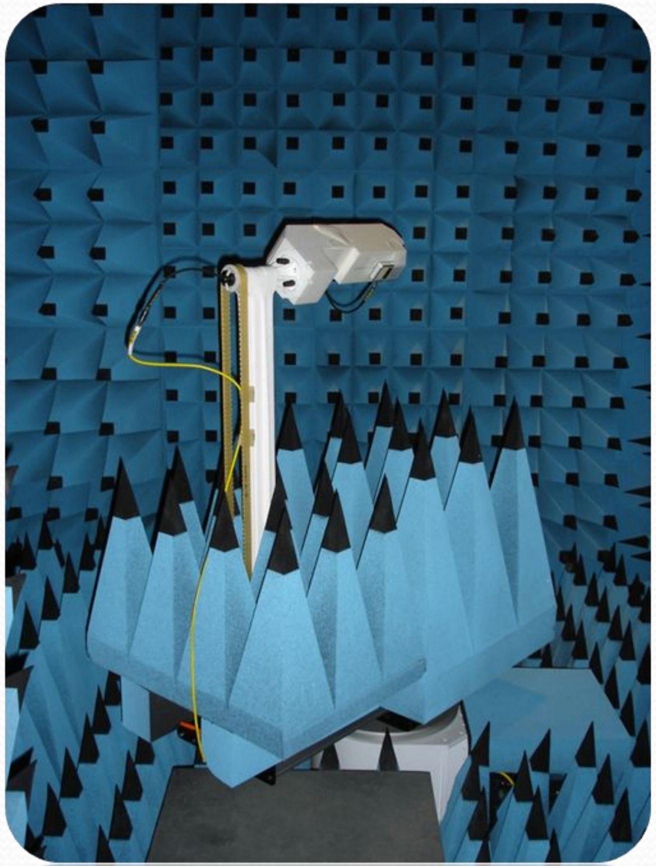
5. Positioners



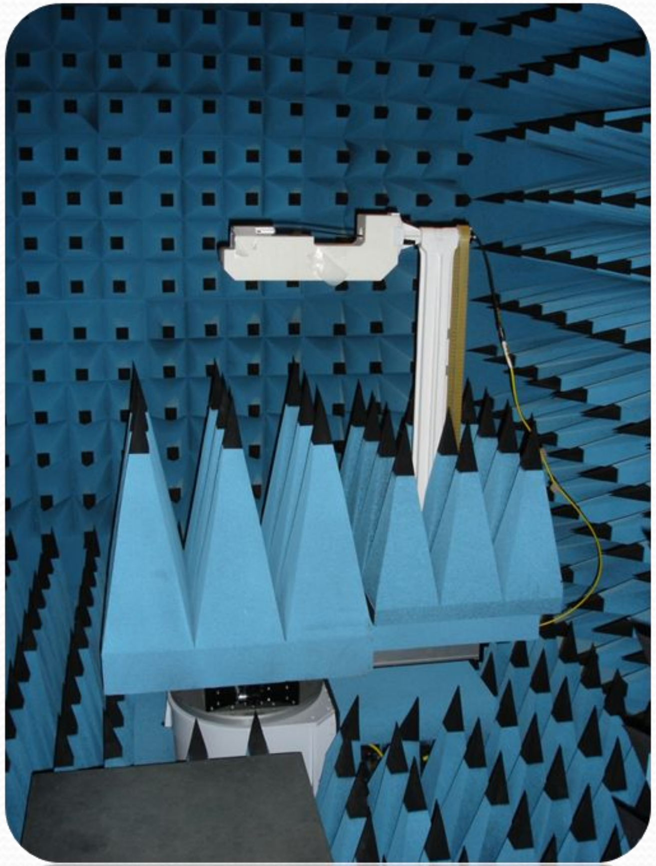


Active Test (TRP/TIS)

5. Positioners



Passive Test



Ripple Test