



HAM Radio Board of Education
NEVER STOP LEARNING

Welcome to the Antenna Summit
Sponsored by NADXA
Northern Arizona DX Association



HAM Radio Board of Education
NEVER STOP LEARNING

Thank You
NAU – Cline Library



HAM Radio Board of Education
NEVER STOP LEARNING

Session 6 – ARRL Antenna Book
Chapter 1 - Antenna Fundamentals



Instructor

- Ron Gerlak
- KG7OH – Amateur Extra Class
- Licensed 1977
- ARRL ANTENNA BOOK 24th Edition 2019
- Q & A at the end of each chapter
- Via Chat
- Email questions to: KG7OH@arri.net - Anytime



Radio System

Radio Puzzle

Transmitter, Receiver and Antenna System

Get a Signal from Your Transmitter to
The other hams Antenna

Propose of Antennas

Radiate and receive electromagnetic
waves

Reciprocity
Always & Never

Dissipated Electromagnetic Waves



Dissipated Electromagnetic Waves

Radiation of Electrometric Waves



Radiated as Heat



Antennas close to ground

Antennas made of very small wire

Reducing Losses = Increased Radiation Efficiency



ANTENNAS

Electromagnetic Waves

E = Electrical Field

Determines Polarization

H = Magnetic Field

ANTENNAS



Array of Light (Next Generation of Antennas)

Tom Schiller, N6BT

Anything Works (Tom Schiller, N6BT)

Everything matters



What Matters

VSWR

Near & Far Fields

Directivity

Height Above Ground

Impedance

Gain

Type of Ground

Take-Off Angle

Free Space



Impedance

- Feed Point Impedance
 - Self and Mutual Impedance
 - Feed Point Impedance is Low where the voltage is low
 - At the center of a dipole
- Resonance

An antenna can be resonant only at one frequency
Current and voltage are in phase



Fields

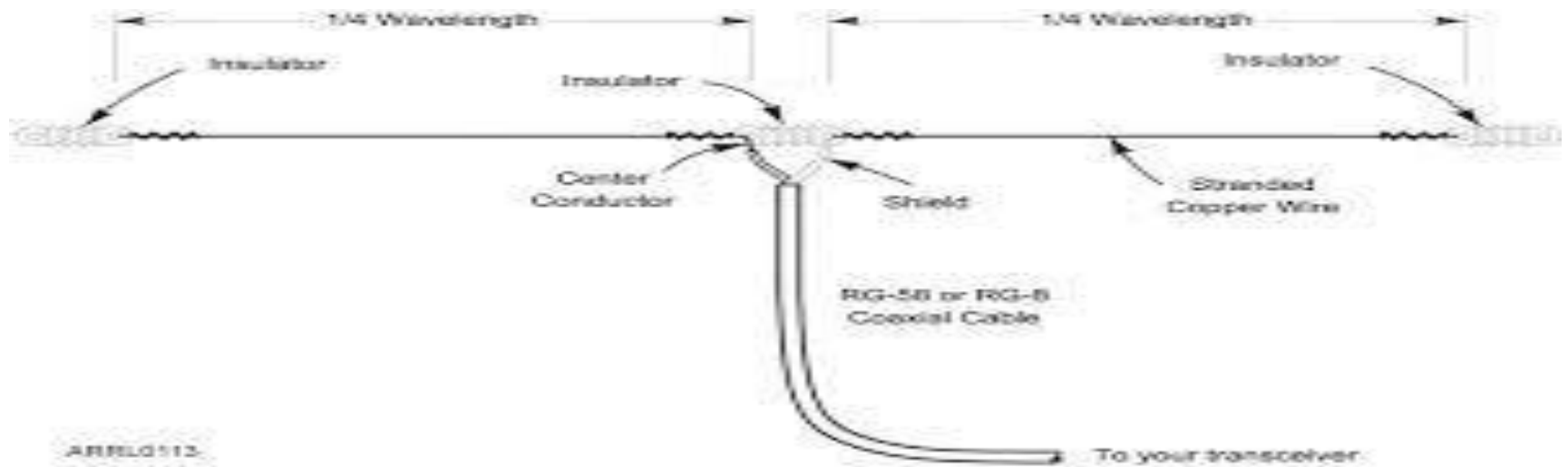
Near Field

Far Field

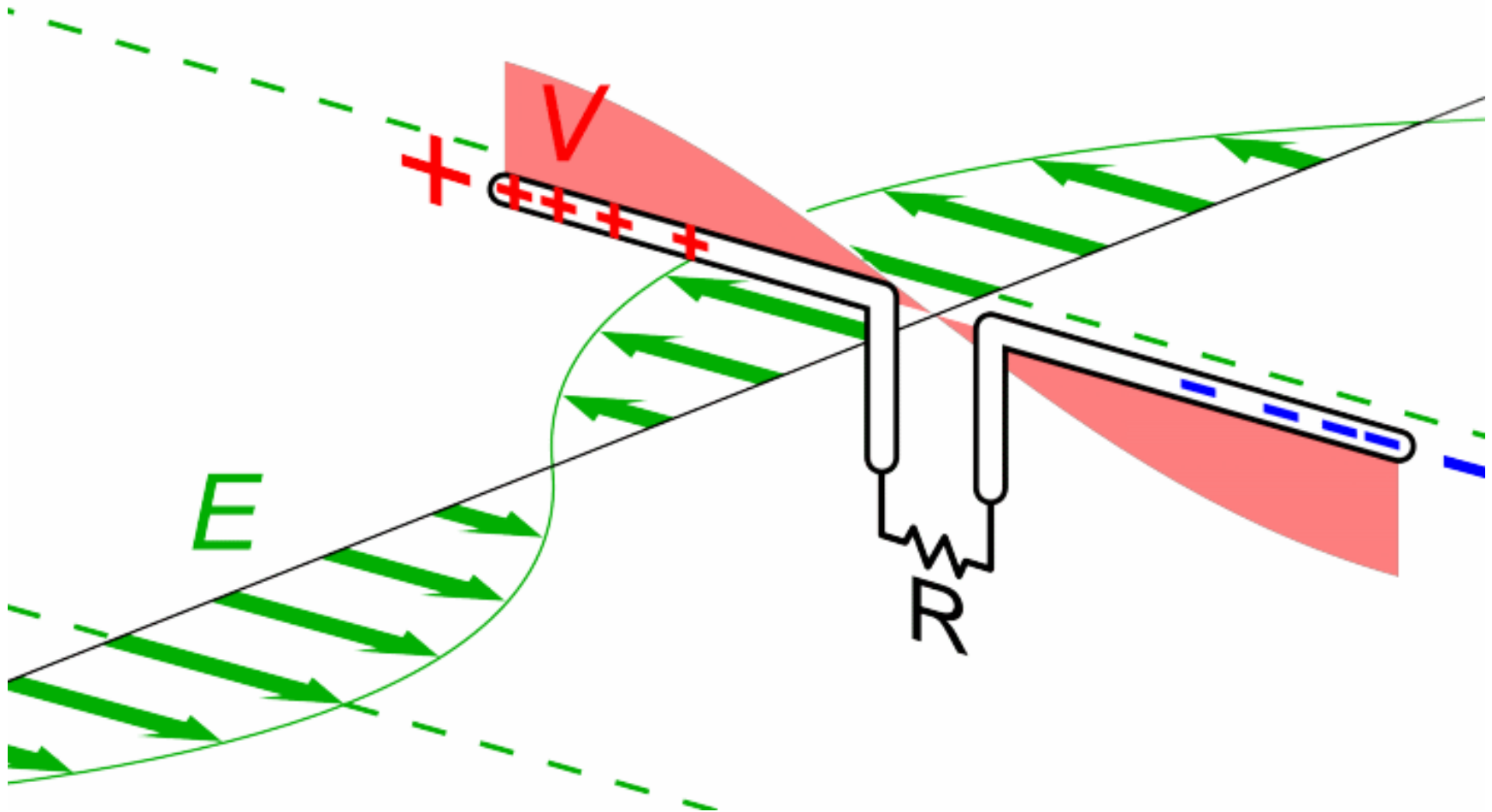
Boundary = $D = 2L^2/\text{Wavelength}$

(Within 2 Wavelengths of the Feed Point)

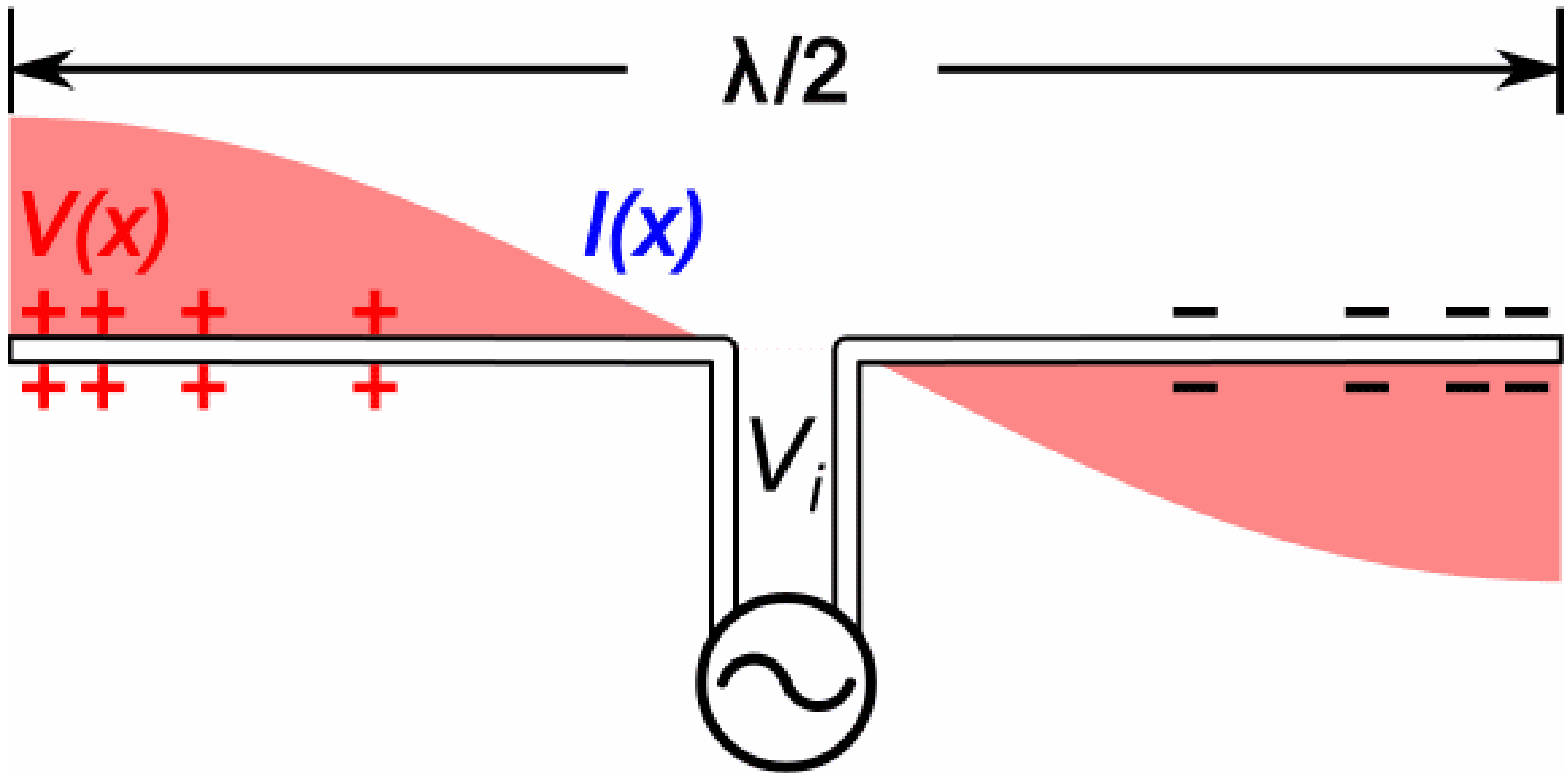
DIPOLE ANTENNA



E and H Wave Forms



Antenna Voltage and Current Distribution

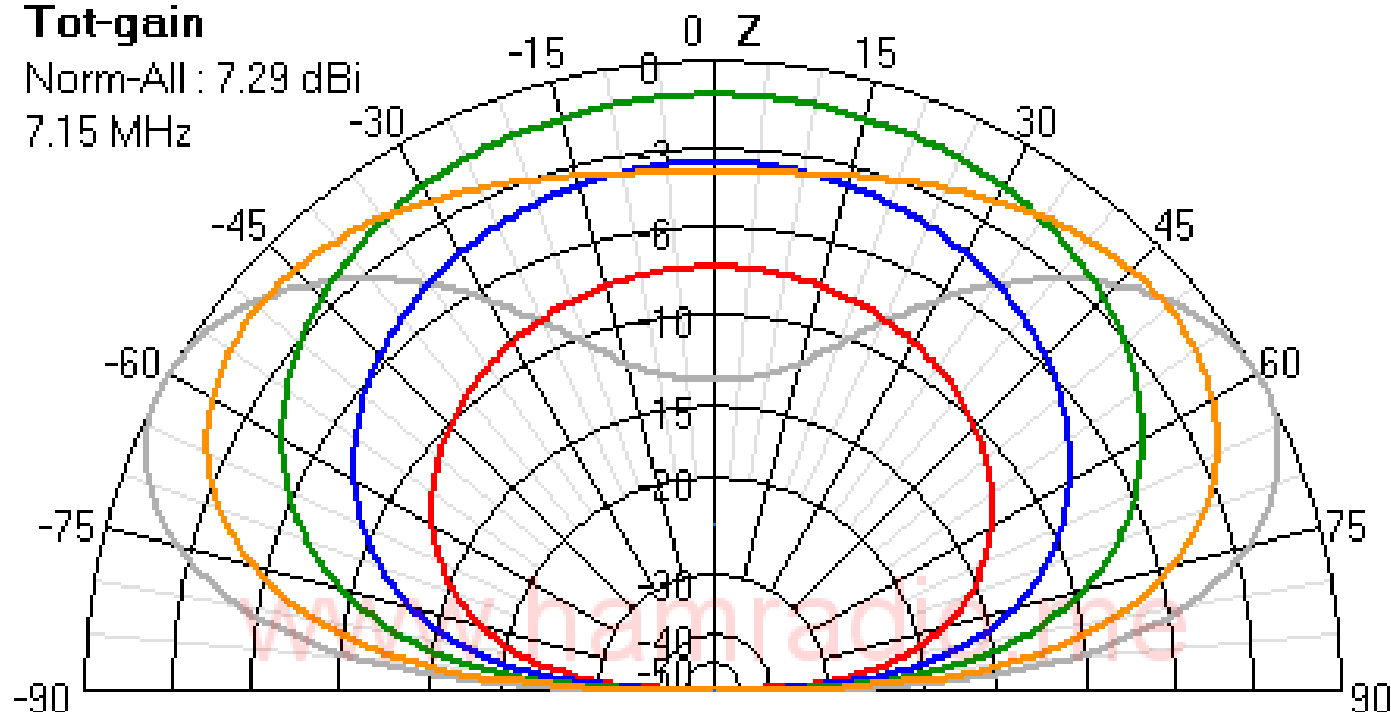


Broadside 40m dipole antenna patterns vs. height above average ground

Tot-gain

Norm-All : 7.29 dBi

7.15 MHz



Red = 40m dipole 6 feet AGL

Blue = 40m dipole 12 feet AGL

Green = 40m dipole 24 feet AGL

Orange = 40m dipole 48 feet AGL

Gray = 40m dipole 65 feet AGL



Decibels

Measures intensity of sound and power

Log scale

Just add them up or subtract them

Power x 2 = +3dB = 3dB Gain

+6dB = +1 S-unit Higher

So Double the power twice = 1 S-unit

Power – dB – S Units

- From 100 watts to 200 watts = + 3dB.
- From 200 watts to 400 watts = +3dB.
- 3dB + 3dB = 6 dB = 1 S-unit



S 6

Power – dB – S Units

- From 100 watts to 200 watts = + 3dB.
- From 200 watts to 400 watts = +3dB.
- 3dB + 3dB = 6 dB = 1 S-unit



S 7

- or -

- Change from a Dipole to a 3 element Yagi
- = + 6 dB_d = 1 S-unit
- Same transmit result doubling + doubling power
- Considerable improvement in receiving



S 6

- or -

- Change from a Dipole to a 3 element Yagi
- = + 6 dB_d = 1 S-unit
- Same transmit result doubling + doubling power
- 1 S-unit improvement in receiving



S 7



Fields and Waves

- RF Waves change with time (Electromagnetic)

E Fields

Electric Wave

90 Degrees to the H Field

Increases with Voltage

Most Relevant to Ham Radio

Describes the Polarization of an Antenna

H Fields

Magnetic Wave

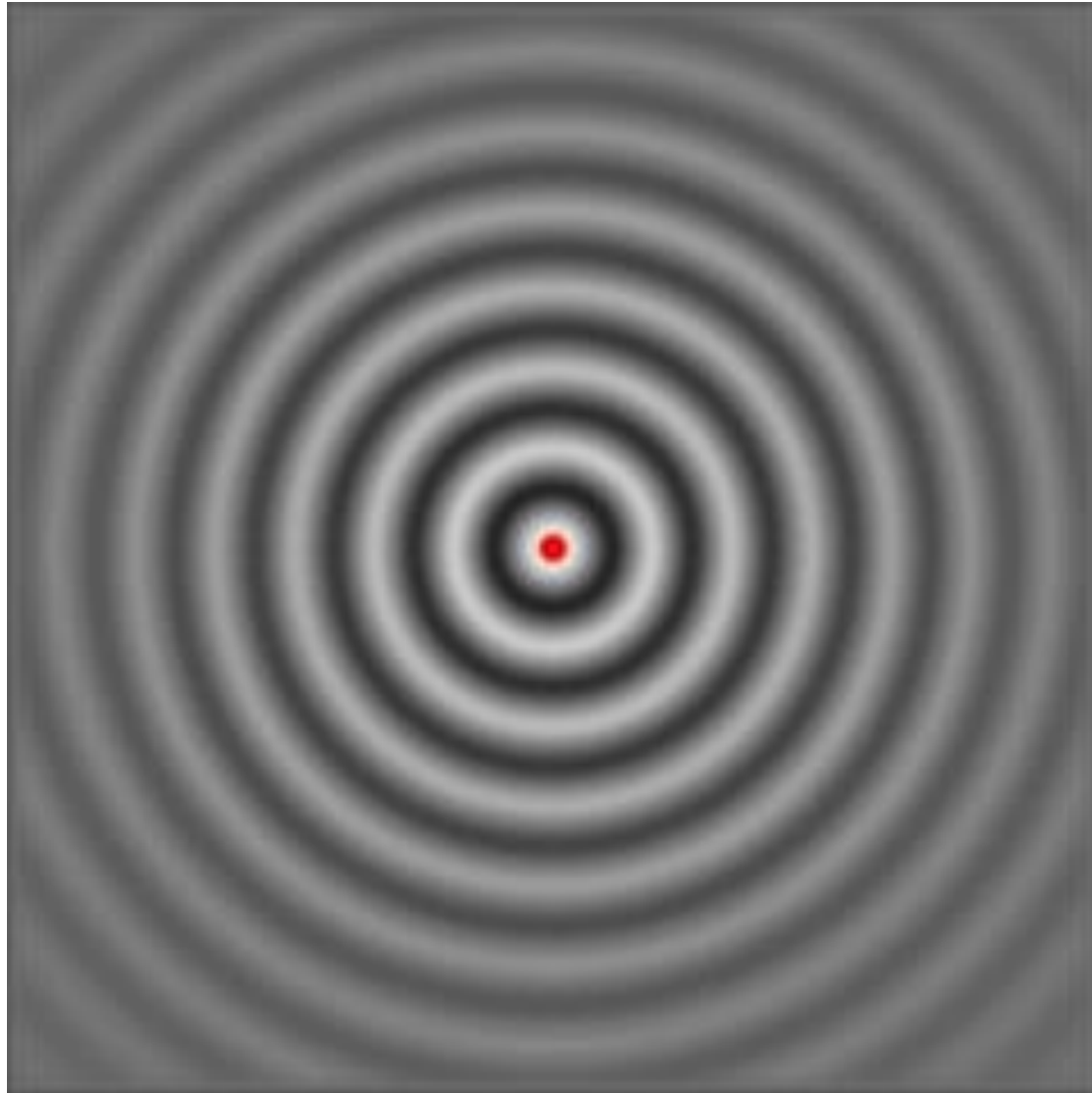
Increases with Current



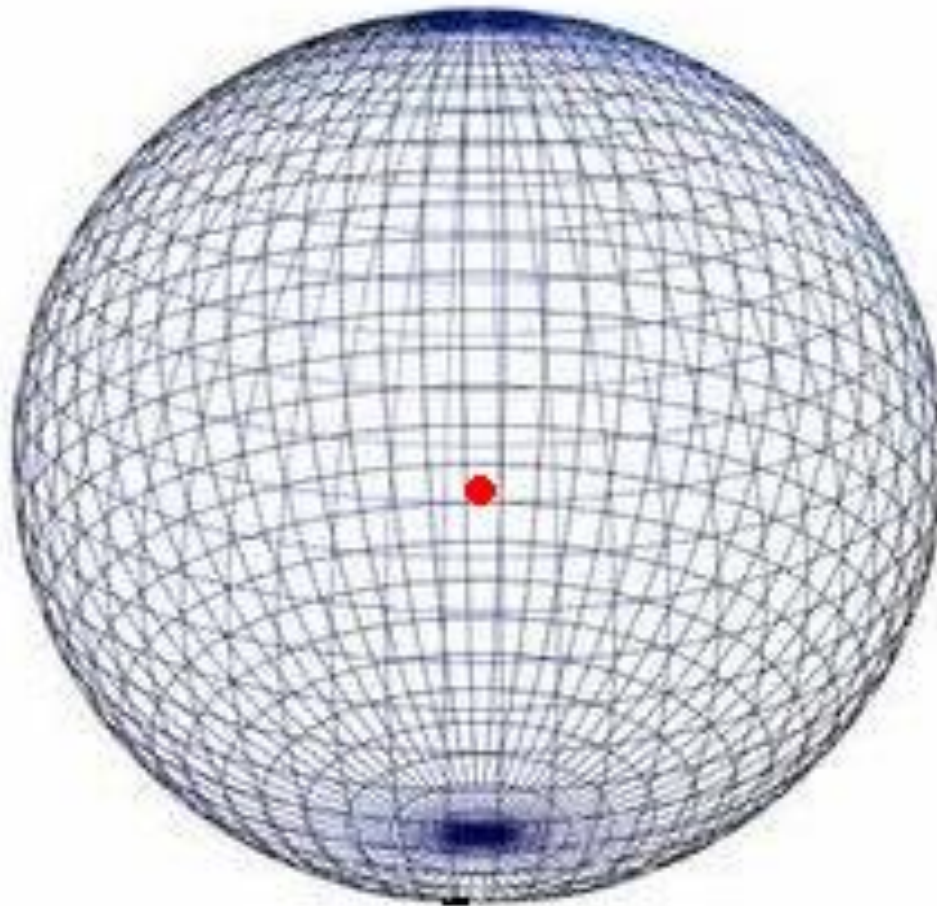
TYPES of PATTERNS

- 3D Pattern
- Azimuthal Pattern
- Elevation Pattern

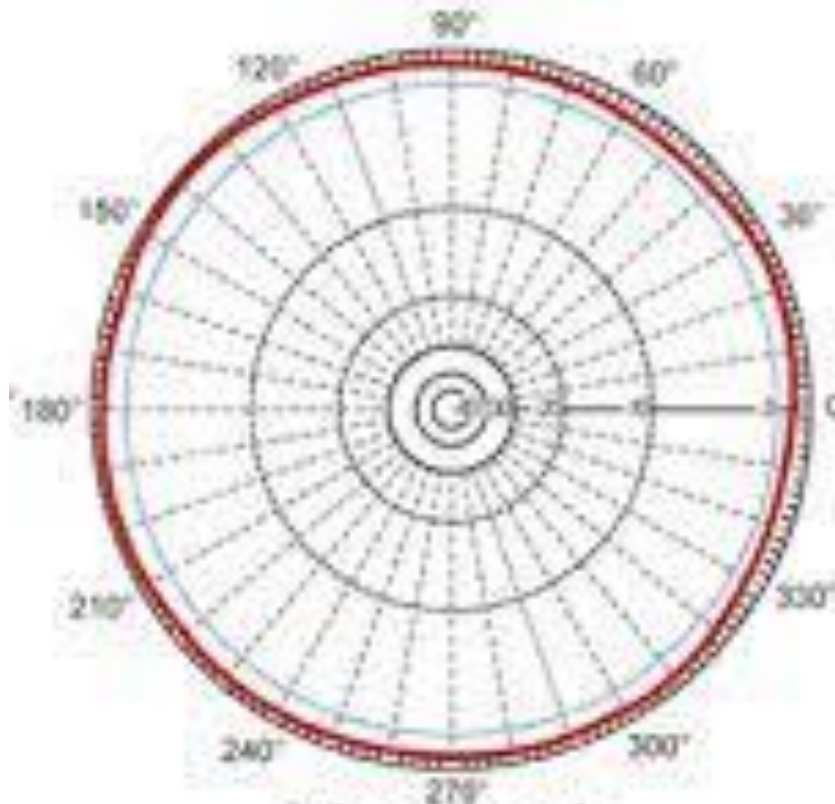
ISOTROPIC ANTENNA



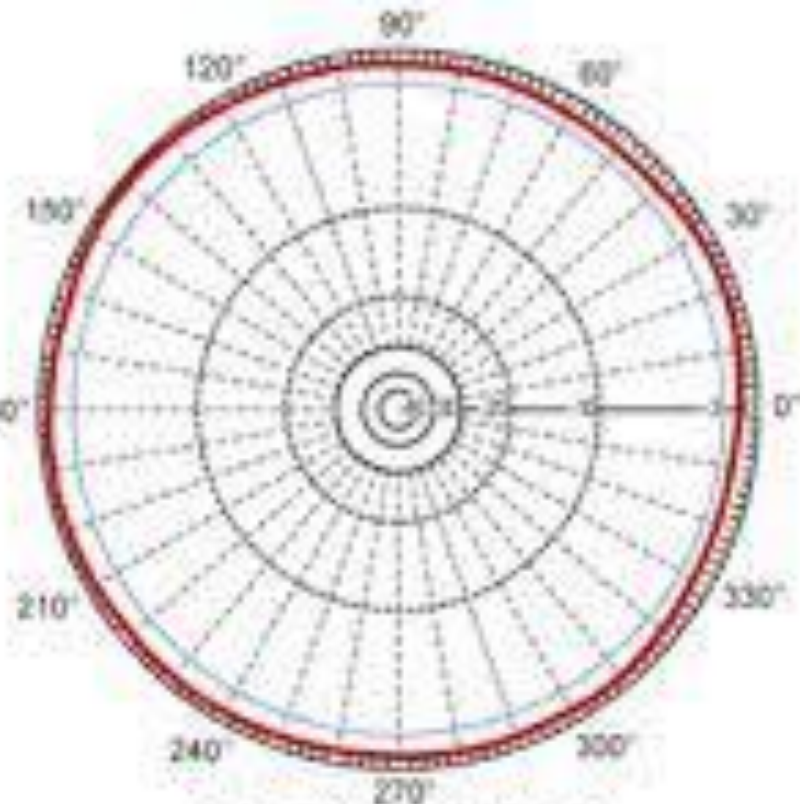
3D ISOTROPIC ANTENNA PATTERN



ISOTROPIC ANTENNA PATTERN SLICE



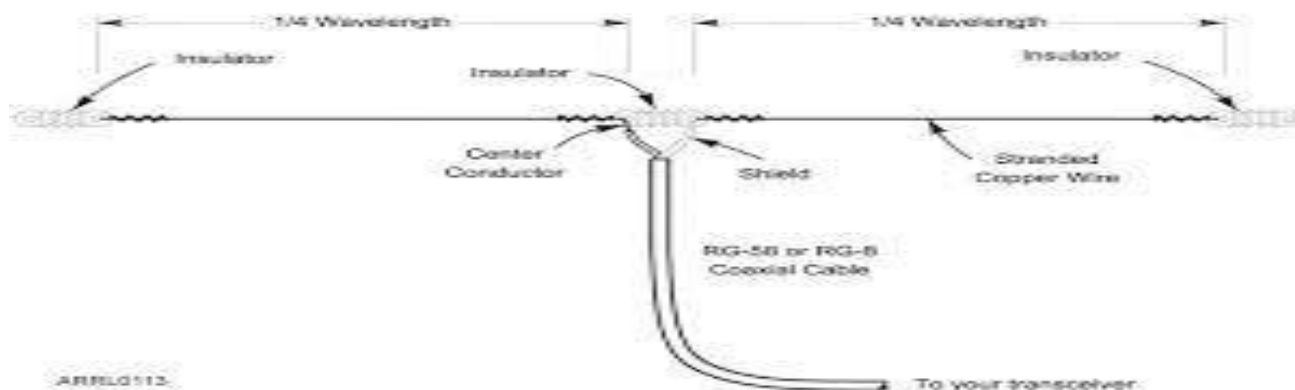
**Vertical
Elevation Pattern**



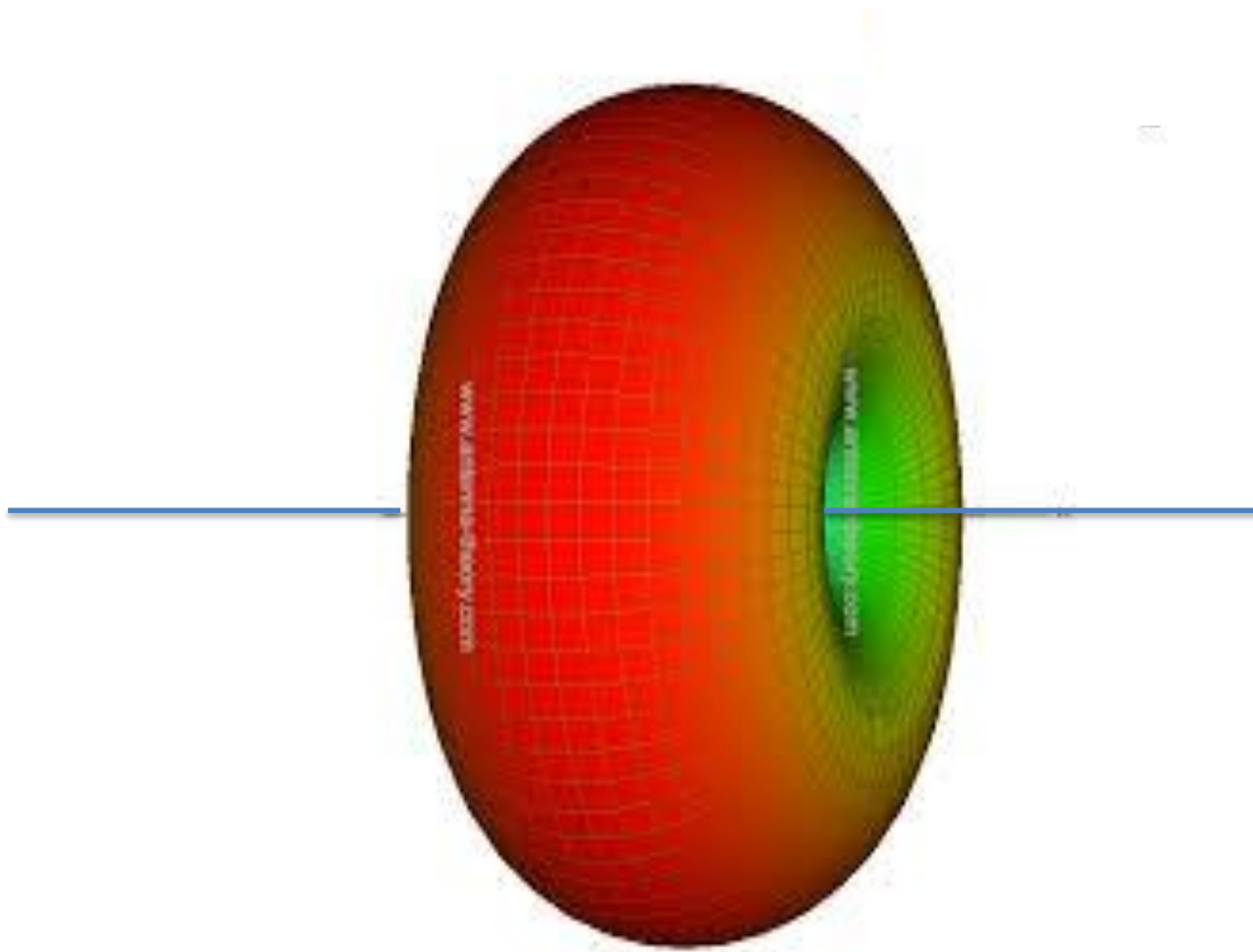
**Horizontal
Azimuthal Pattern**

Horizontal Dipole

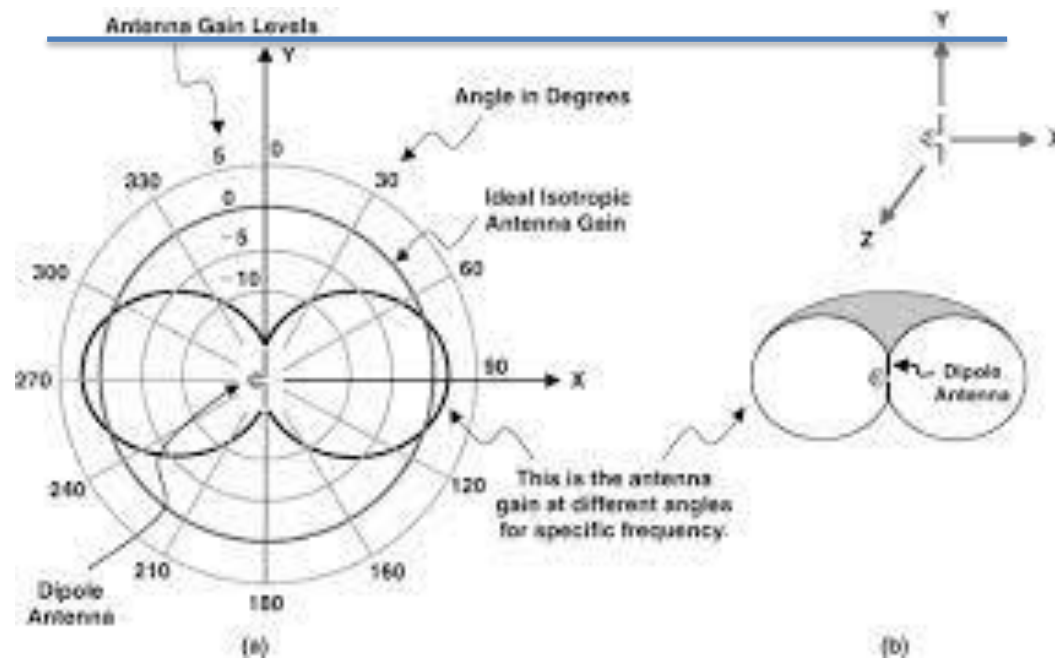
The dipole is the simplest type of real antenna from a theoretical point of view. Most commonly it consists of two conductors of equal length oriented end-to-end with the feed-line connected between them.



3D DIPOLE ANTENNA PATTERN



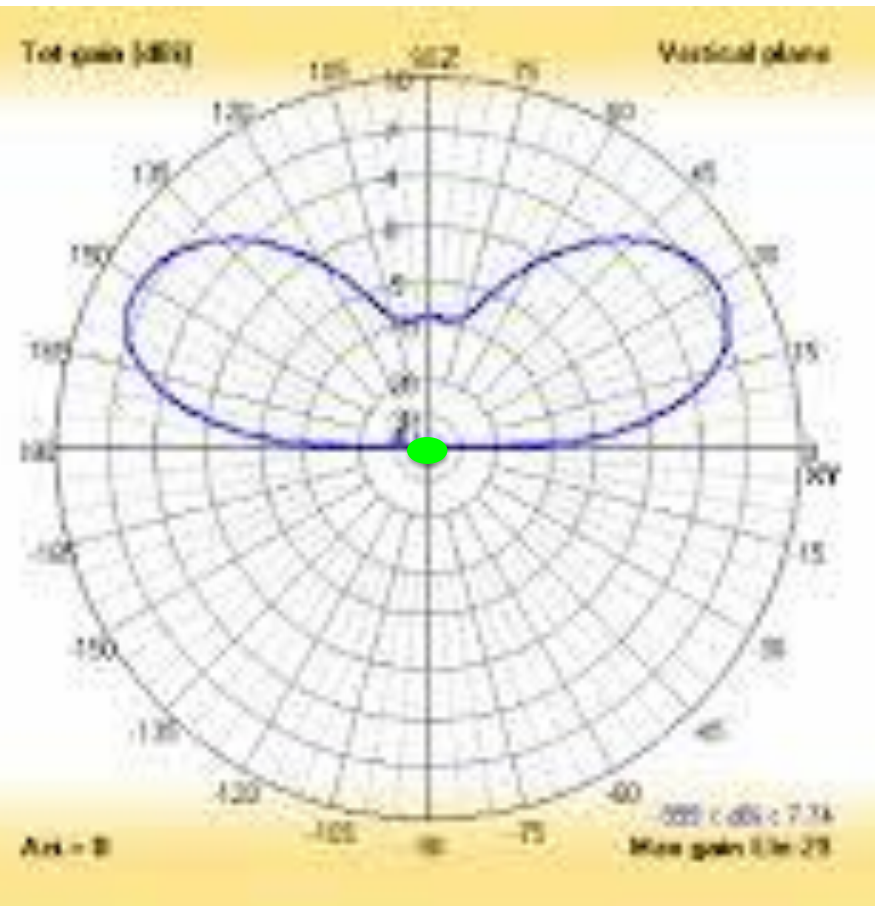
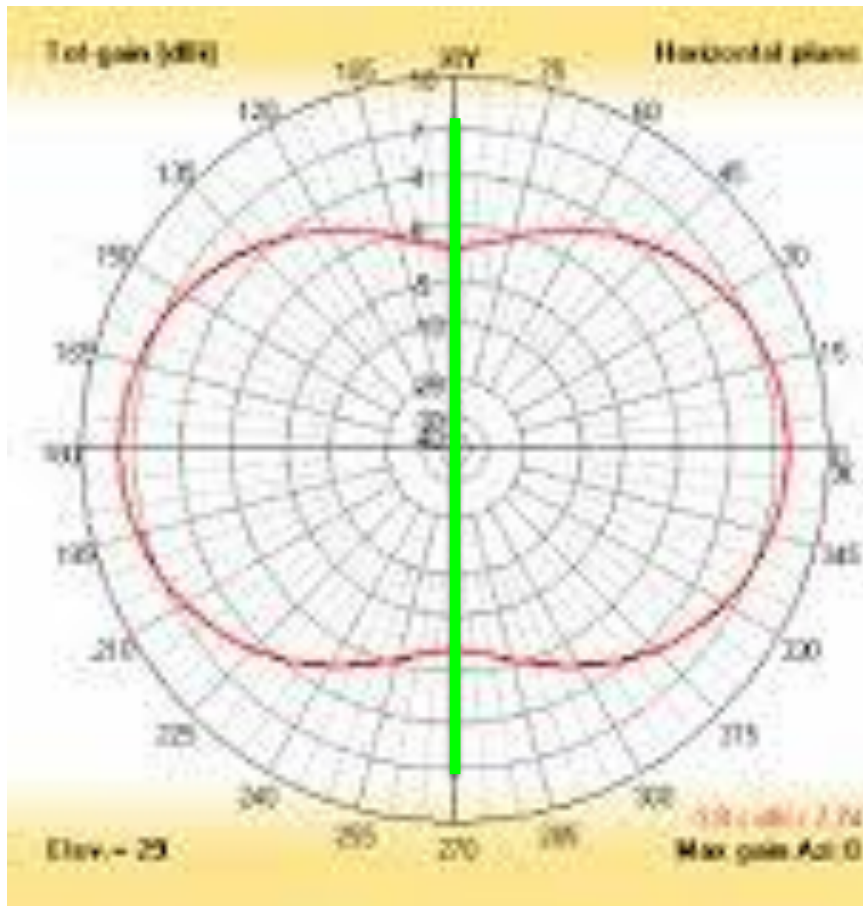
3D DIPOLE PATTERN SLICE



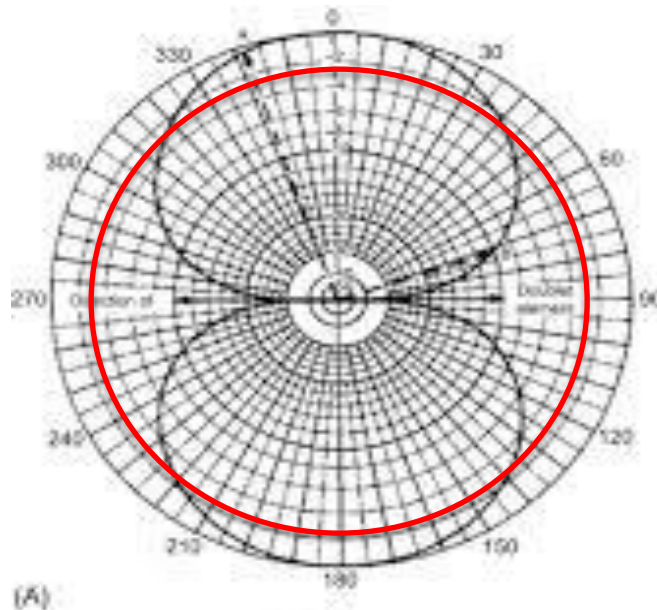
DIPOLE PATTERN

Horizontal Pattern
Azimuth Pattern

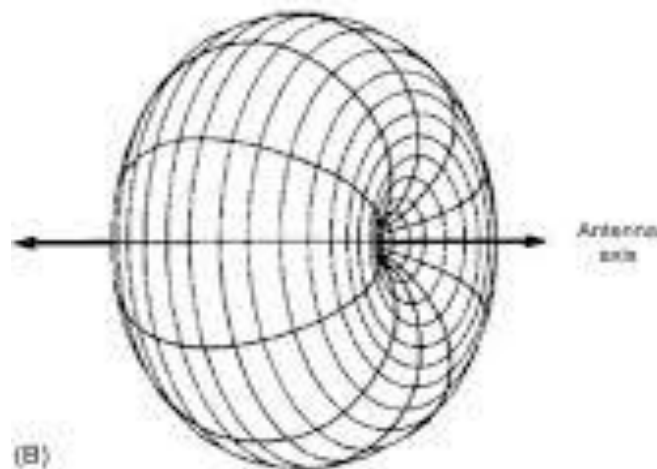
Vertical Pattern
Elevation Pattern



Horizontal Dipole Pattern



Azimuth Pattern
Isotropic shown in Red



3D Pattern



Gain

- Dipole has 2.15 dB_i gain over an Isotropic Antenna
- Signal from the ends is redistributed to the broadside



Gain

Antennas are passive devices and do not generate any “extra” power.

Where does the gain come from???

Gain is achieved by redistribution of pattern



DB Referance

- Isotropic antenna as the reference
Dipole has 2.15 dB_i Gain

Yagi has ≈ 6 dB_d Gain

Dipole antenna as the reference

Yagi has ≈ 8.15 dB_i Gain

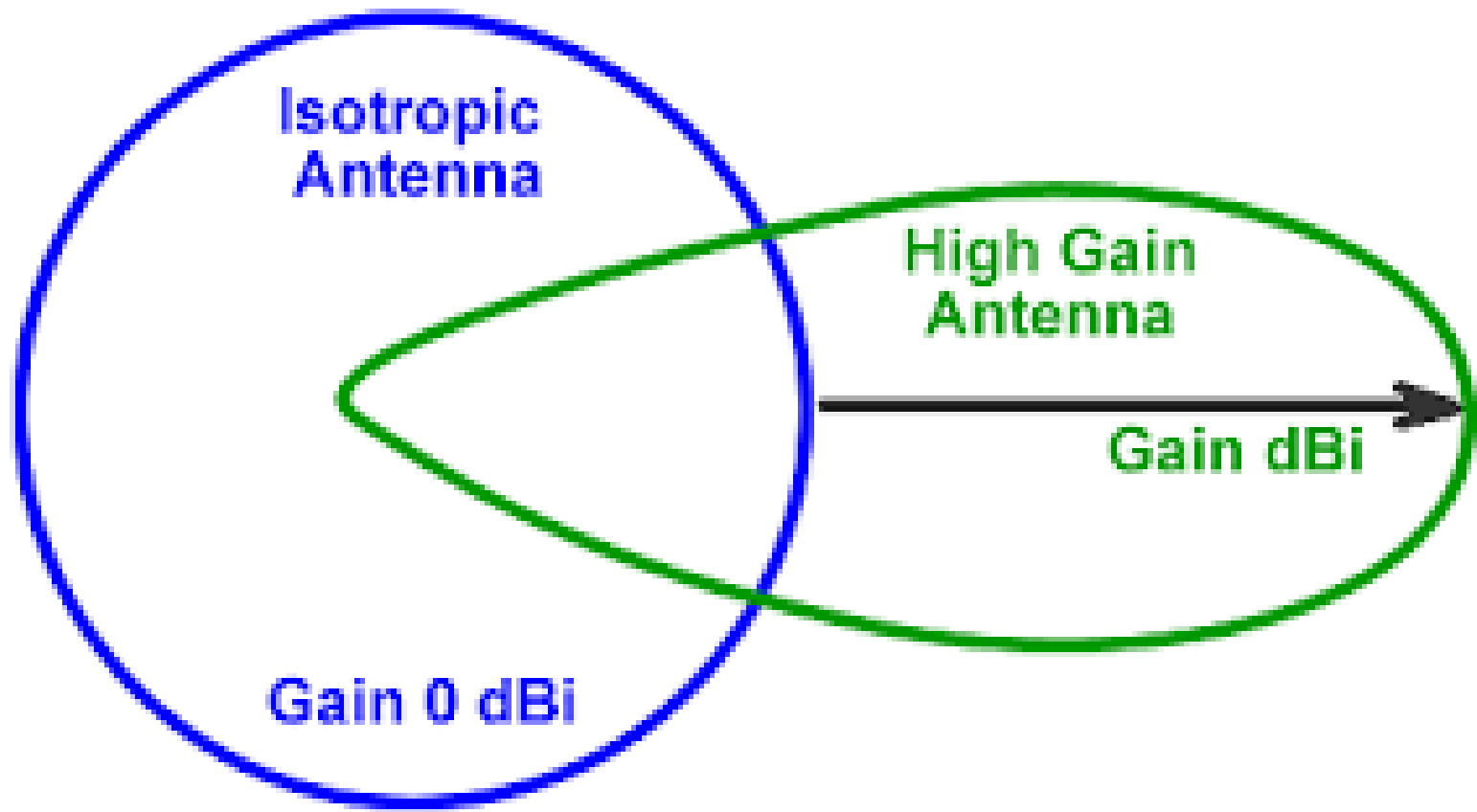
(Same antenna)

Isotropic antenna as the reference

Tri-Band Yagi 10 – 15 - 20

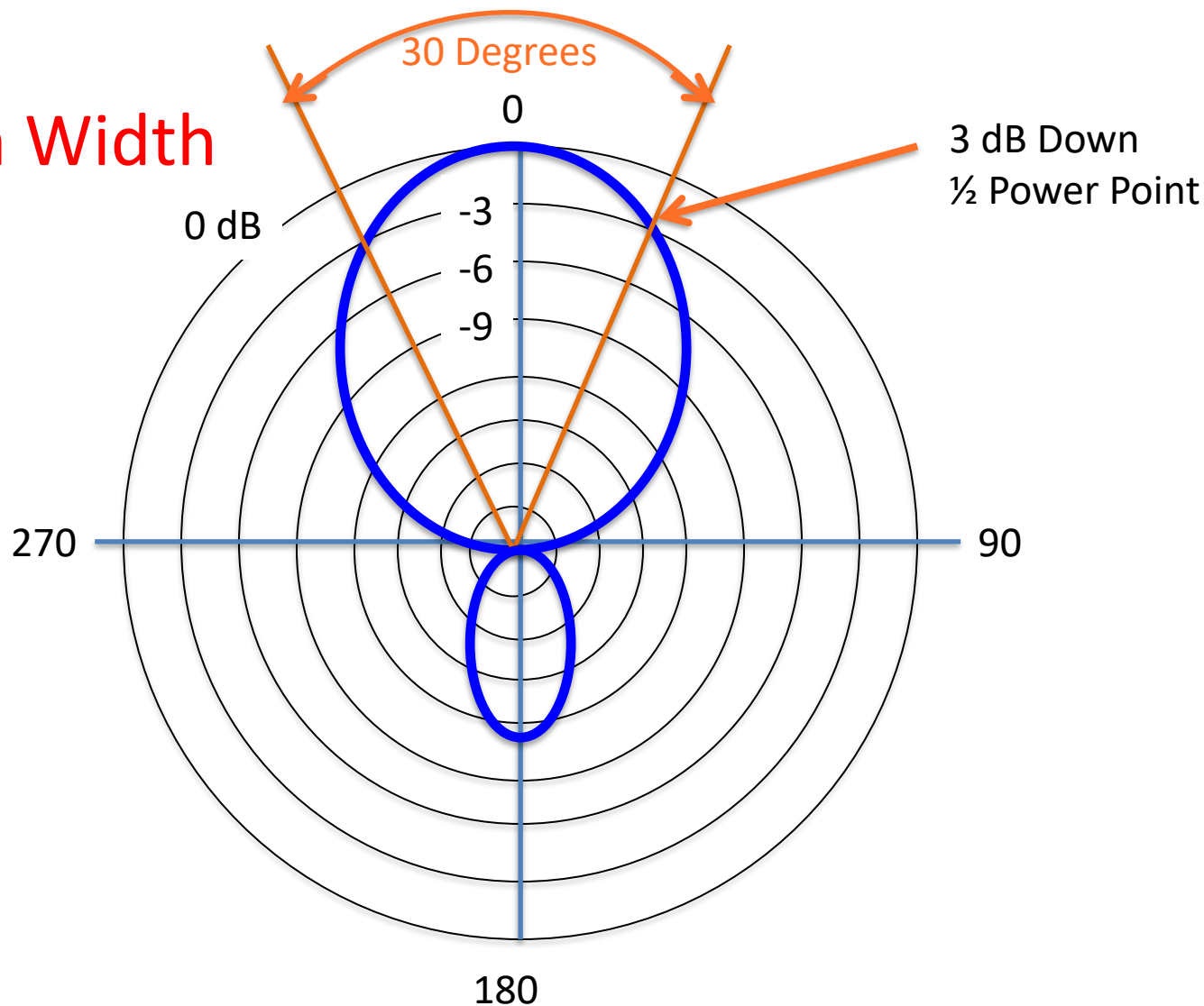


YAGI (Gain Antenna) PATTERN (Azimuth)



Azimuth $\frac{1}{2}$ Power Points of a Yagi

Beam Width





Q - Quality

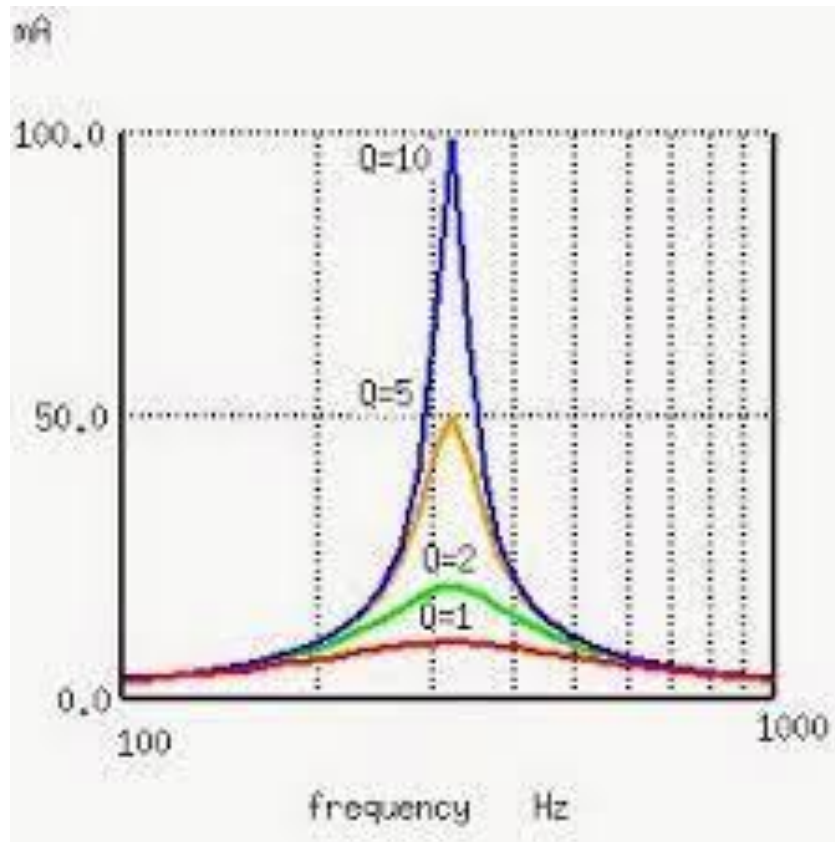
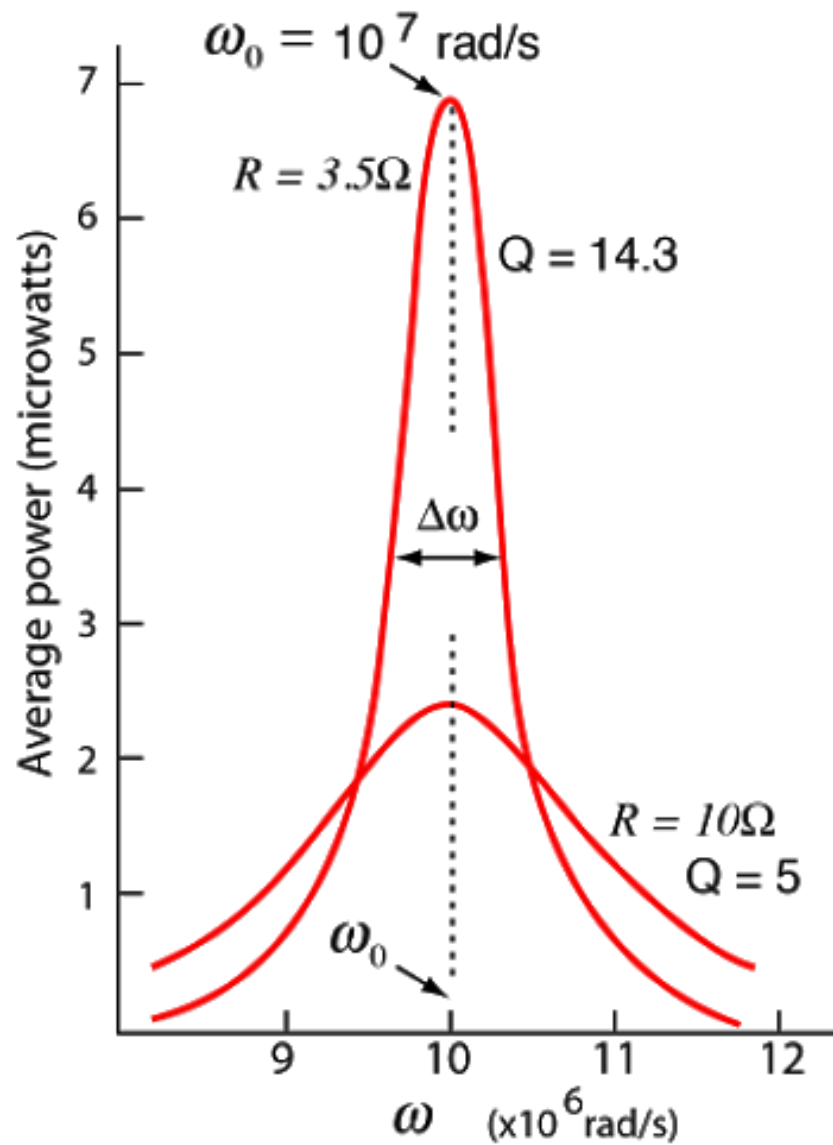
- Narrower Beam width = Higher **Q**
- Higher the Gain = Higher **Q**

More Gain

More Directivity

More Selectivity

Q - Quality





Q - Quality

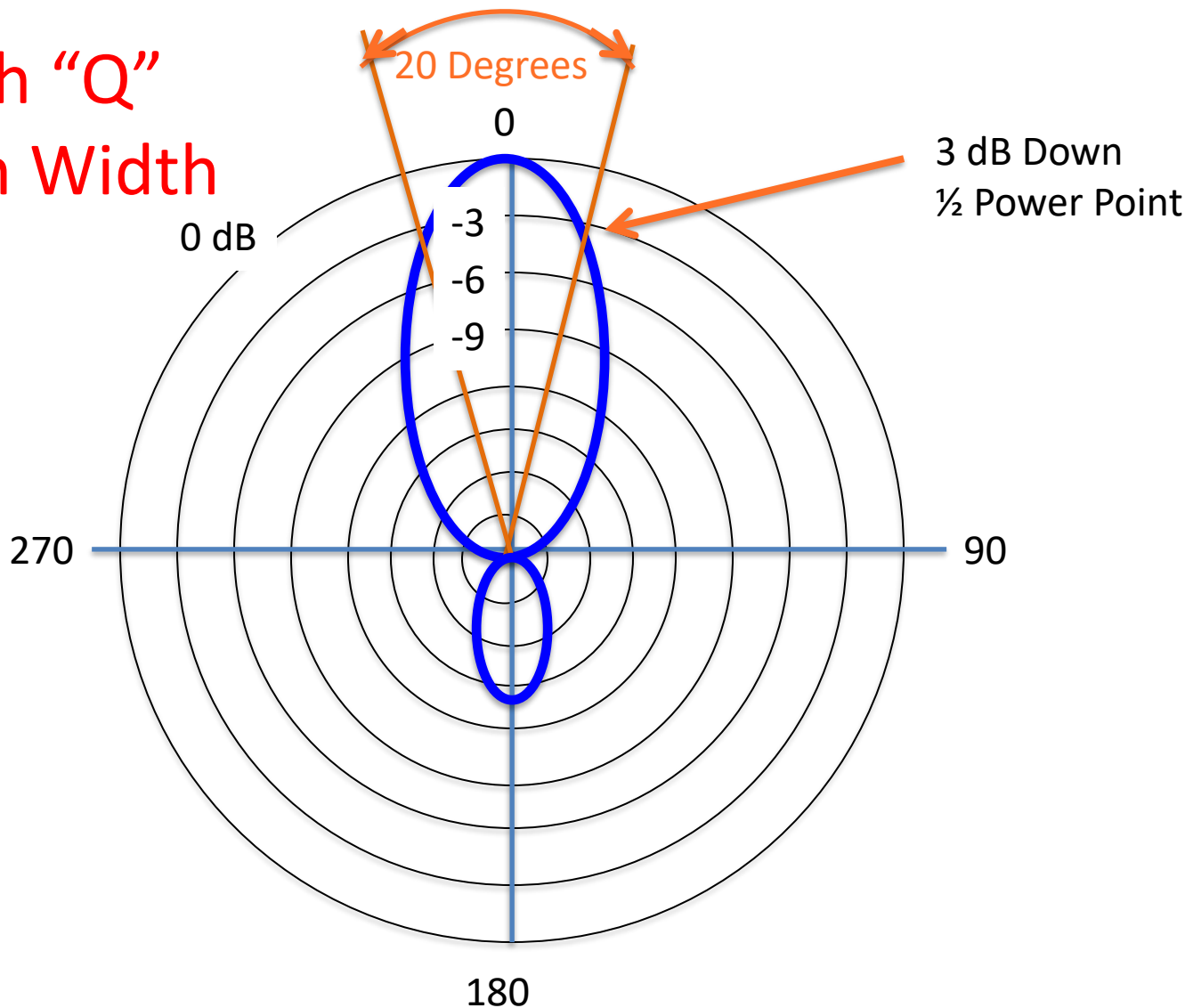
Beam Width of Antennas

Transistors

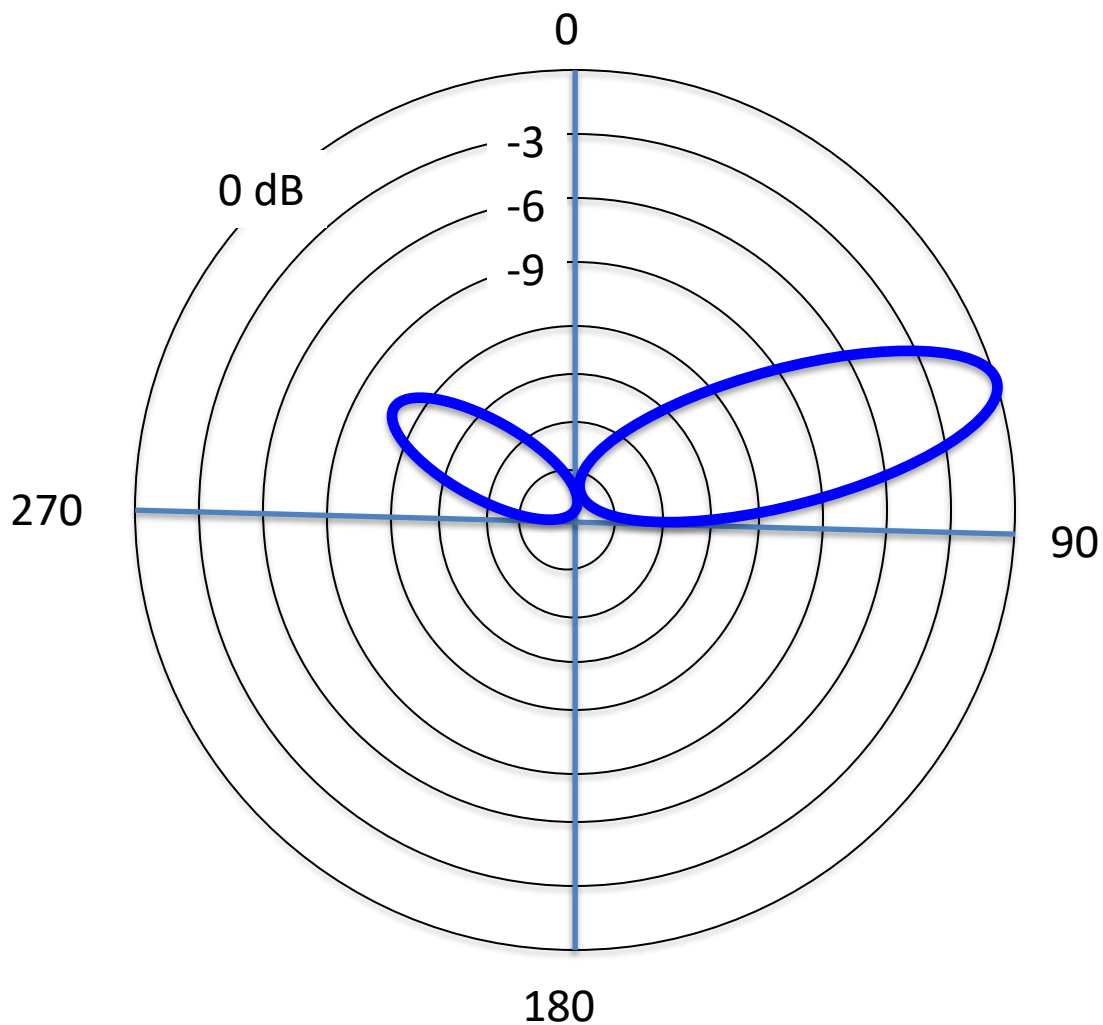
Resonant RLC Circuits

Azimuth $\frac{1}{2}$ Power Points of a Yagi

High "Q"
Beam Width



Elevation Pattern of a Yagi





Polarization

- Horizontal
- Vertical
- Circular
- Sky-waves



Scaling

- Scaling

Length, Spacing, Boom & Element Diameter



ERP & EIRP (E_i RP)

Effective Radiated Power

- TPO = 100 watts = 50 dBm
- Transmission line attenuation = 2.4 dB
- Losses in RF connectors and coupling = 1.7dB
- Antenna gain = 7.5 dB_i
- $EIRP = 50 \text{ dBm} - 2.4 \text{ dB} - 1.7 \text{ dB} + 7.5 \text{ dB} =$
 $53.4 \text{ dBm} = 219 \text{ watts}$



Safety

- Thermal Effects
- Athermal Effects
- Radiation
- Power Density
- Safe Levels
- Pacemakers



Thermal Effects of RF

Microwave cooks using RF Energy

Body's Natural Resonant Frequency

35 MHz – Grounded

70 MHz - Insulated from ground

SAR – Specific Absorption Rate

MPE – Maximum Permissible Exposure



Athermal Effects of EMR

Electromagnetic Radiation

Electromagnetic Field

Energy Fields – At Home/Work

- Electric Drill, 500 – 2000 milligauss
- Hair Dryer, 200 – 2000 milligauss
- Electric Blanket, 30 – 90 milligauss
- HF Transceiver , 10 – 100 milligauss

Some studies – Weak association

EMF & Malignant Conditions

More studies – No association



Radiation

Ionizing – Always a danger

- X Rays
- Gamma Rays
- Nuclear Power

Non-Ionizing – Sometimes a Concern

RF Field

60 Hz Field



Power Density

Scientific community disagree on guidelines

Measurement equipment is expensive

ARRL RF Awareness Guidelines

Page 1.24, Table 1.3

ARRL RF Awareness Guidelines

- Keep people away from antennas
- Keep mobile power to < 25 watts
- Make antenna heights $> 35'$
- Keep equipment covers installed
- Don't point directional antennas toward people
- Use a speaker microphones with HT radios
- Keep a distance from transformers & fans



Safe Exposure Levels

STATIONS MUST BE EVALUATED

- Controlled Environments
- Uncontrolled Environments
- E Field
- H Field
- Different Frequencies
- Time Period Averaging

Experts Do Not Agree



Safe Exposure Levels

NO EVALUATIONS REQUIRED

- 100 maximum watts okay on all Bands except:
- 50 watts or less on:
 - 12 Meters
 - 10 Meters
 - VHF
 - UHF

(Table B, Page 1.21)



Pacemakers

- DISCUSS THIS WITH YOUR PHYSICIAN!



HAM Radio Board of Education
NEVER STOP LEARNING

Session 6 – ARRL Antenna Book
Chapter 2 - Dipoles and Monopoles

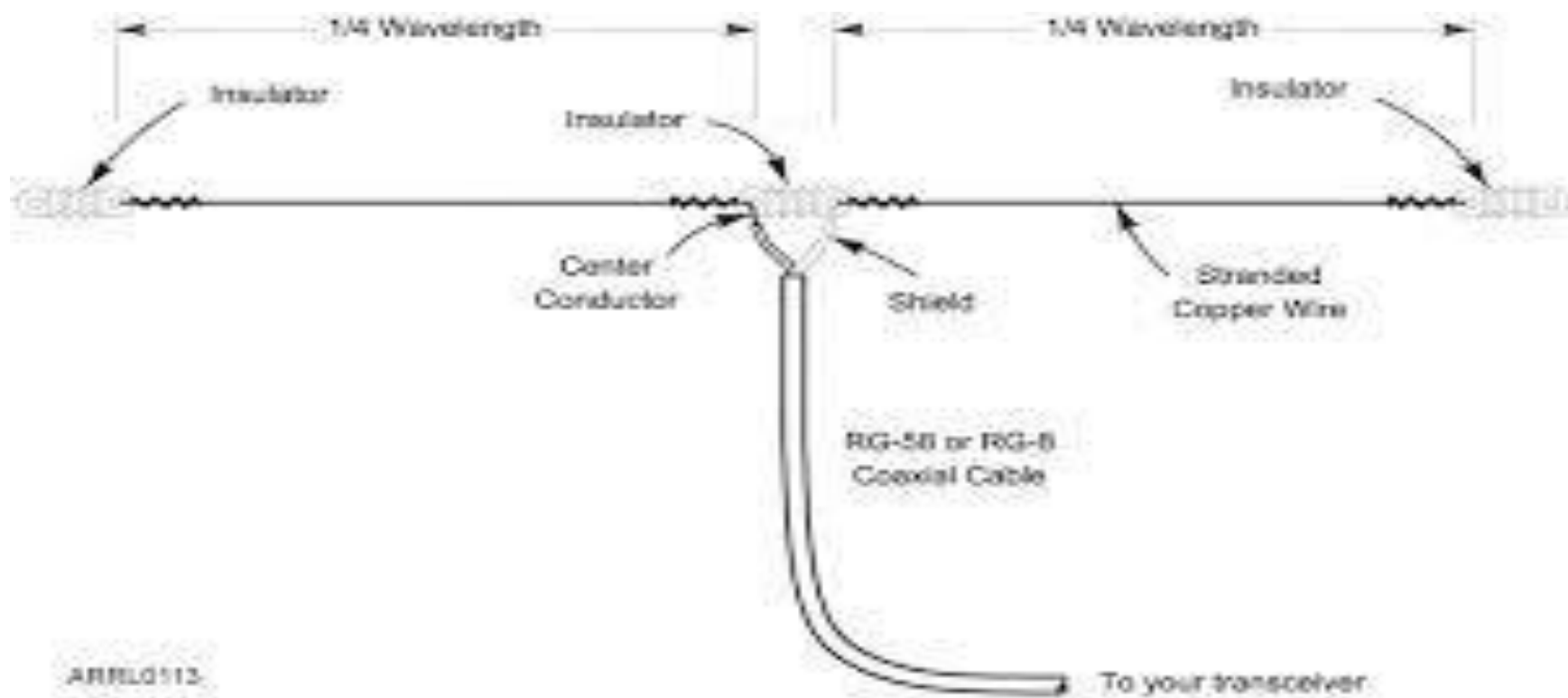


Dipoles and Monopoles

- Effects of Conductor Diameter
- Radiation Patterns and Effects of Ground
- Feed Point Impedance
- Effects of Frequency on Radiation Pattern
- Folded Dipoles
- Vertical Dipoles
- Off Center Fed (OCF) Dipoles
- Monopoles
- Folded Monopoles

DIPOLES

- Fundamental Antenna





Dipole Length Calculations

$\lambda/2$ Dipole Resonant Length (in free space)
 $491.786 / f(\text{in MHz}) = \text{Length in Feet}$

Example of 40 Meter Dipole:

$$491.786 / 7.2 = 68.29'$$



Dipole - K Factor Length Correction for Diameter

Dipole Length Corrected for Diameter of #12 AWG
(.969 - .976) Page 2.2, Figure 2.3

$$491.786 / 7.2 = 68.29'$$

$$.97 \times 491.786 / 7.2 = 66.3 \text{ Feet}$$



Dipole - Velocity Factor

Dipole Length Corrected for Insulated Wire

Reference Material says about .95%

My experience says about .99%

$$491.786 / 7.2 = 68.29'$$

$$.97 \times 491.786 / 7.2 = 66.25'$$

$$.99 \times .97 \times 491.786 / 7.2 = 65.60'$$

Dipole – Type of Ground

- Very Poor Soil Ground
- Good Ground
- Salt Water

Dipole – Height Factor

Resonant length changes up and down as the height above ground changes.



Dipole Length

USE THIS FORMULA IN THE FIELD

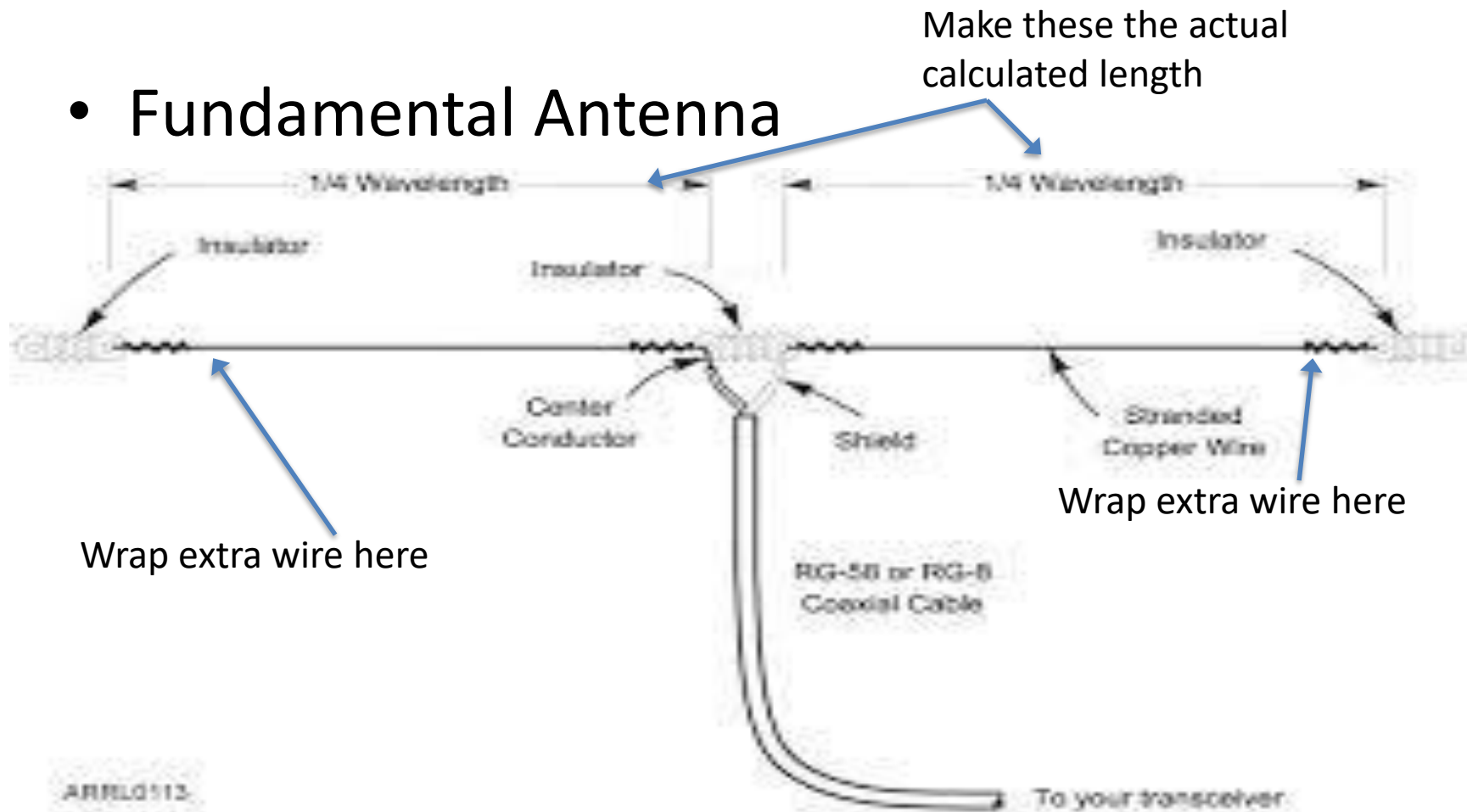
- The book says $468 / f$ for $\lambda/2$
- Soooo $234 / f(\text{MHz}) = \text{the } \lambda/4 \text{ element Length}$
- Cut it 2 feet longer and wrap it back on itself.

Element length =
 $234 / f$
then add 2' just in case

- $234 / 7.2 = 32.5$ Then add 2 = 34.5

DIPOLES

- Fundamental Antenna



ARRLQ513

Dipole Length

- Check SWR dip with Antenna Analyzer
- Adjust as needed:
Lengthen Antenna Lowers Dip Frequency

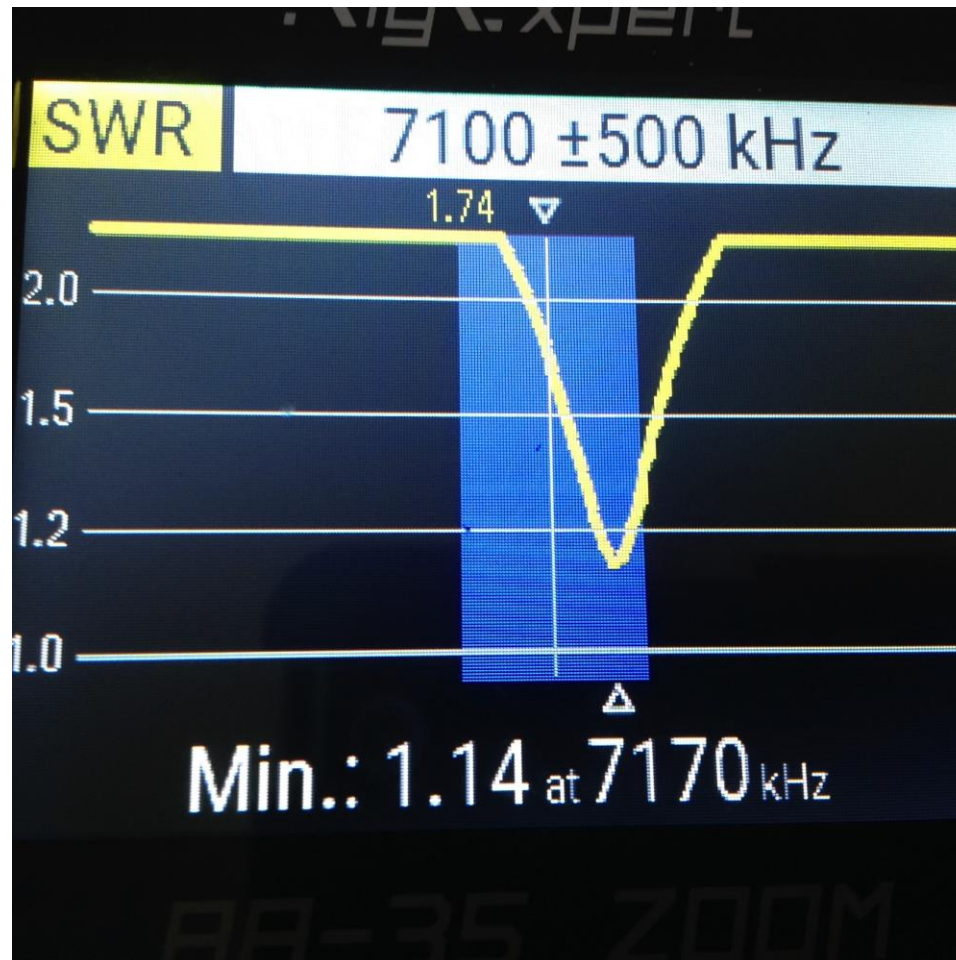
Dipole Length

To lower the dip make the antenna longer



Dipole Length

Needs to be more longer



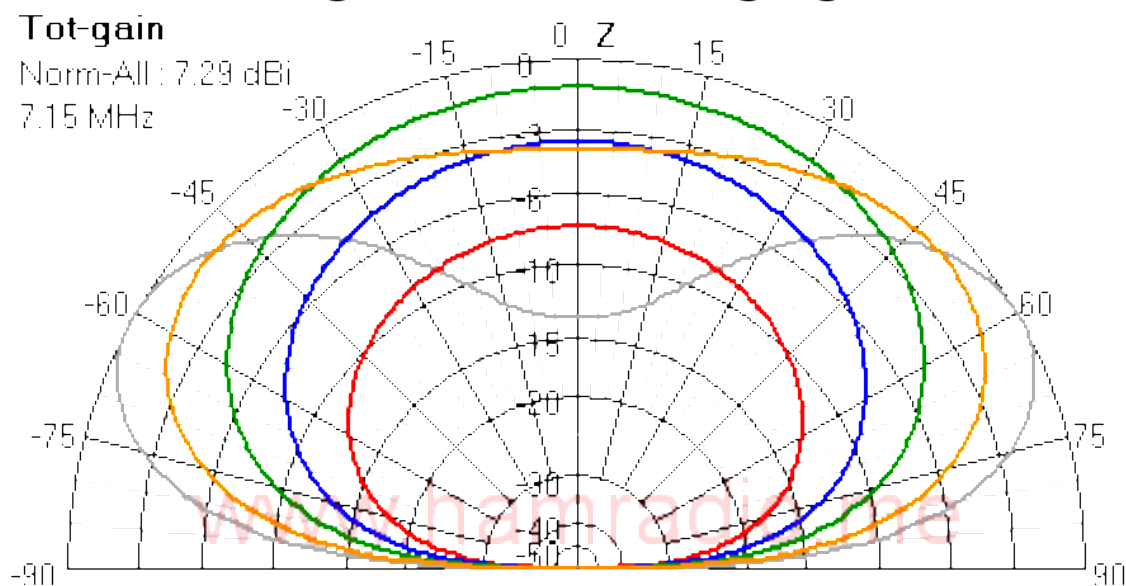
Dipole Length

Just the right length



Dipoles Height Above Ground

Broadside 40m dipole antenna patterns
vs. height above average ground



Red = 40m dipole 6 feet AGL

Blue = 40m dipole 12 feet AGL

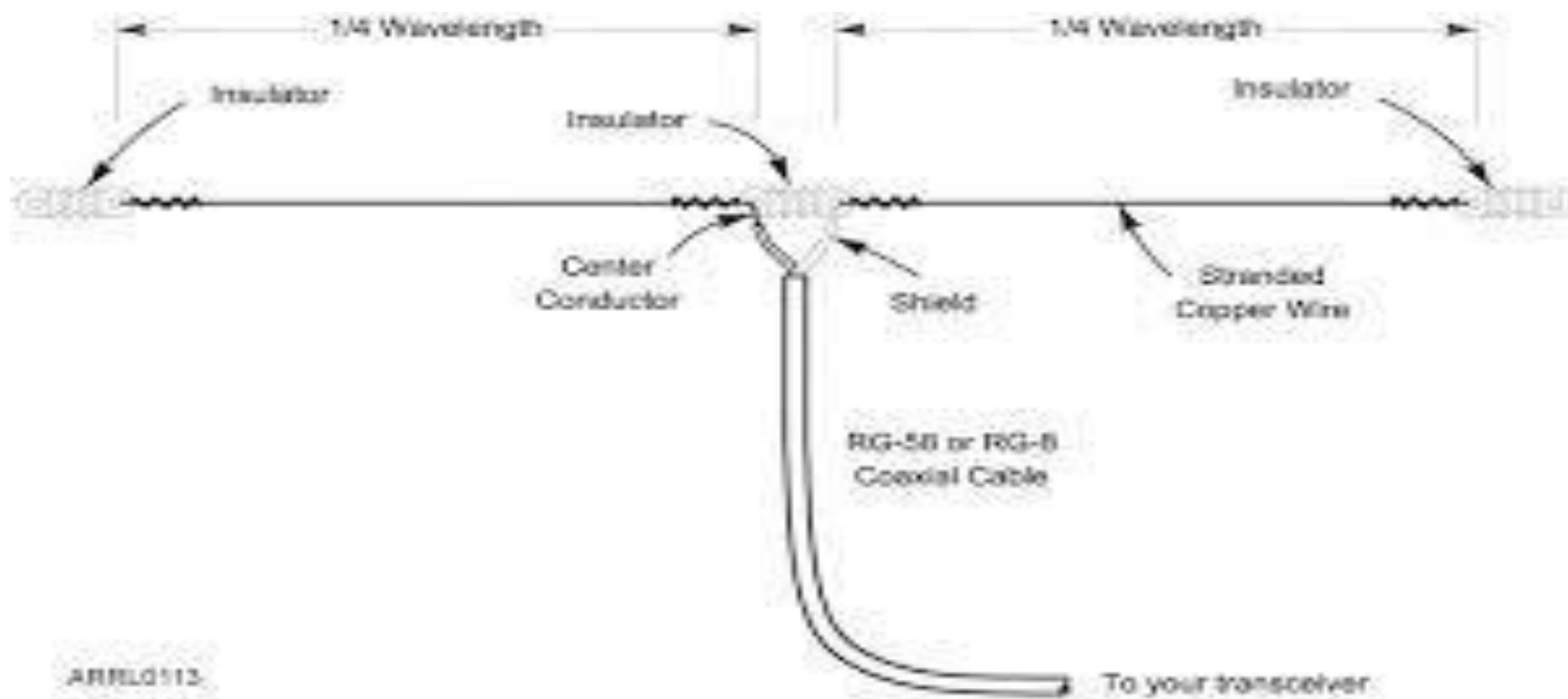
Green = 40m dipole 24 feet AGL

Orange = 40m dipole 48 feet AGL

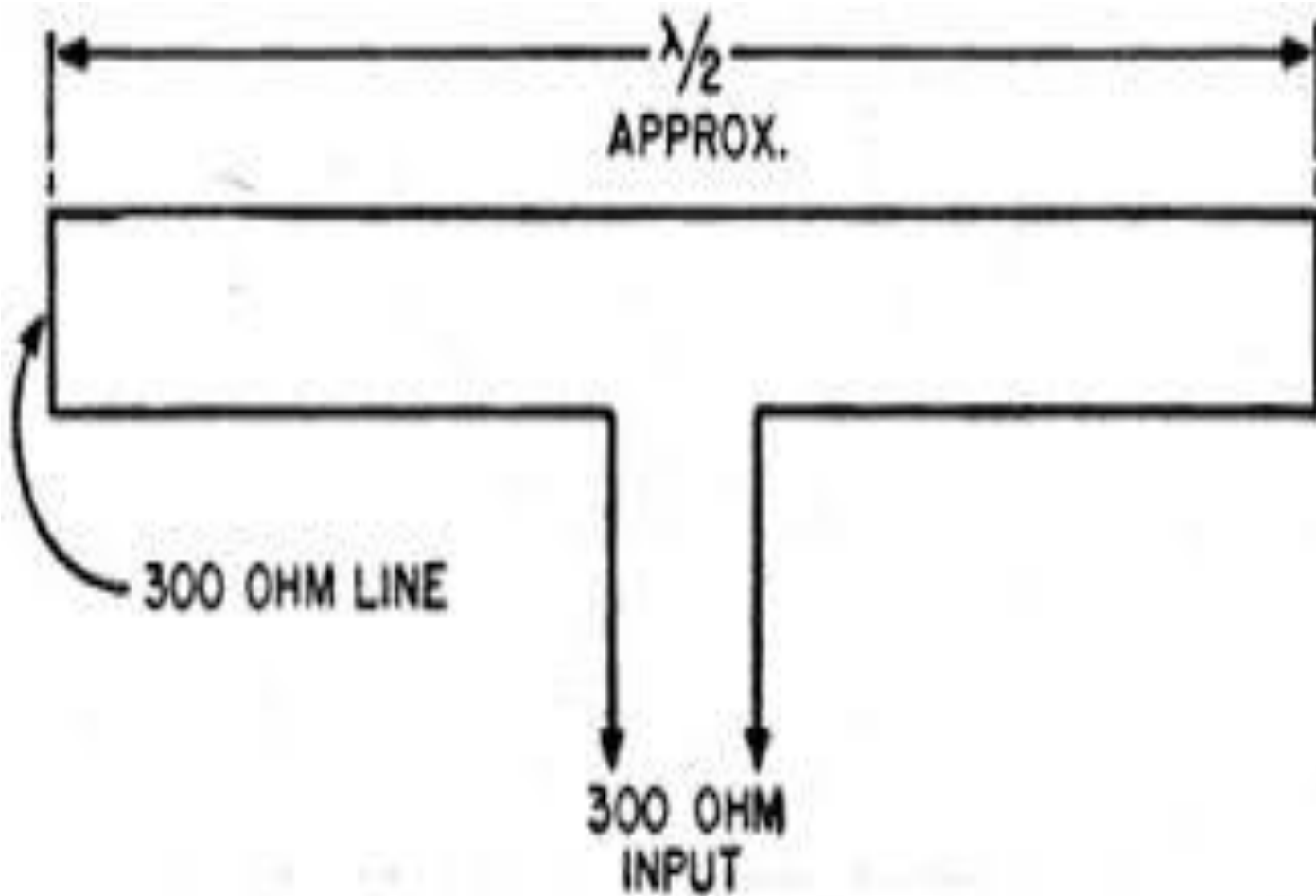
Gray = 40m dipole 65 feet AGL

DIPOLES

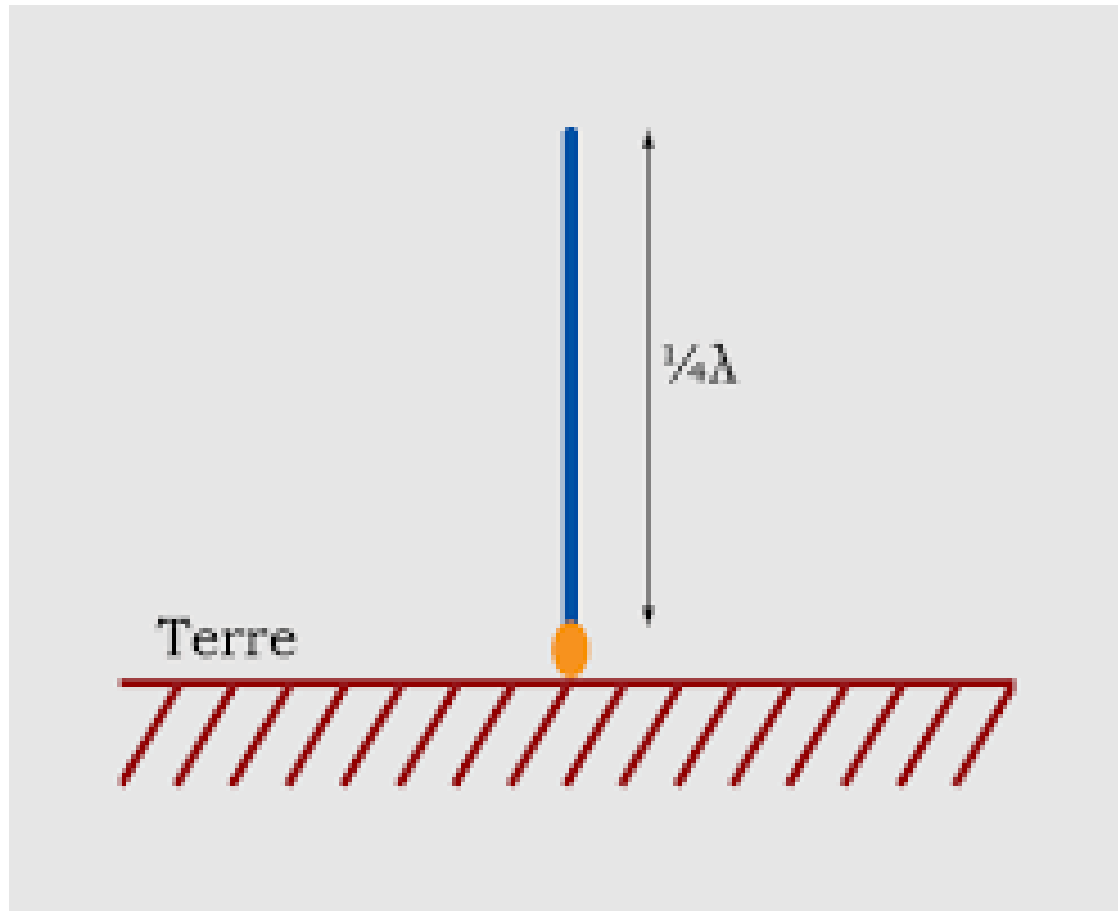
- Fundamental Antenna



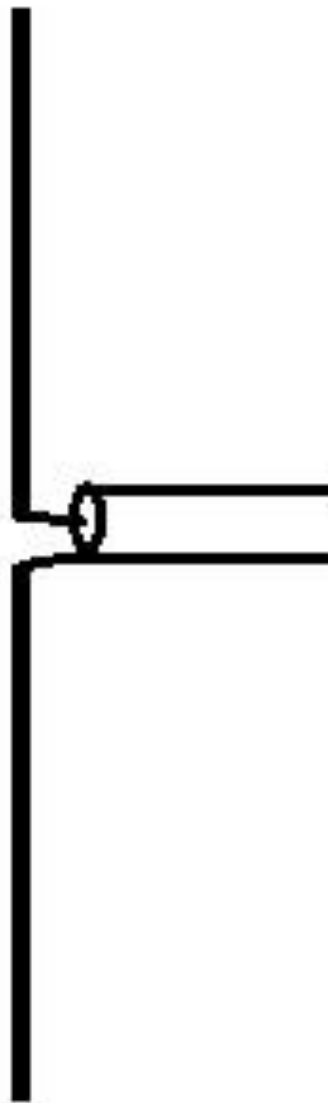
Folded Dipole



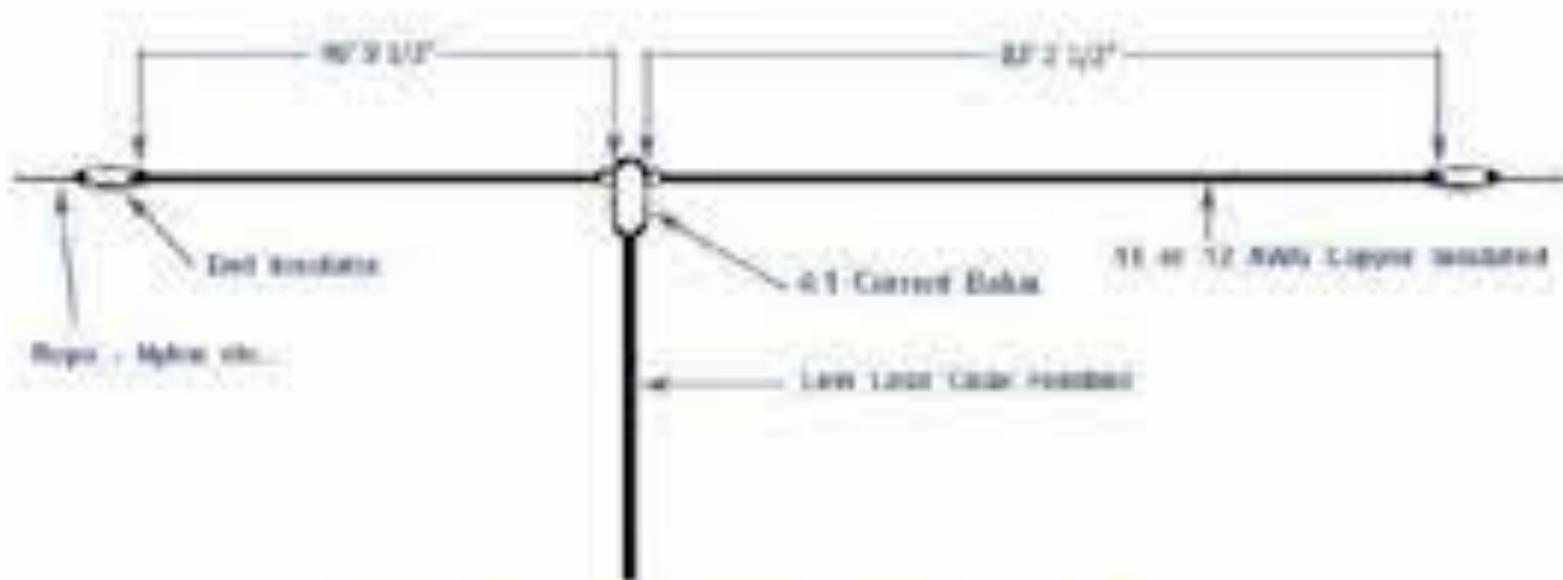
Monopole / Vertical



Vertical Dipole

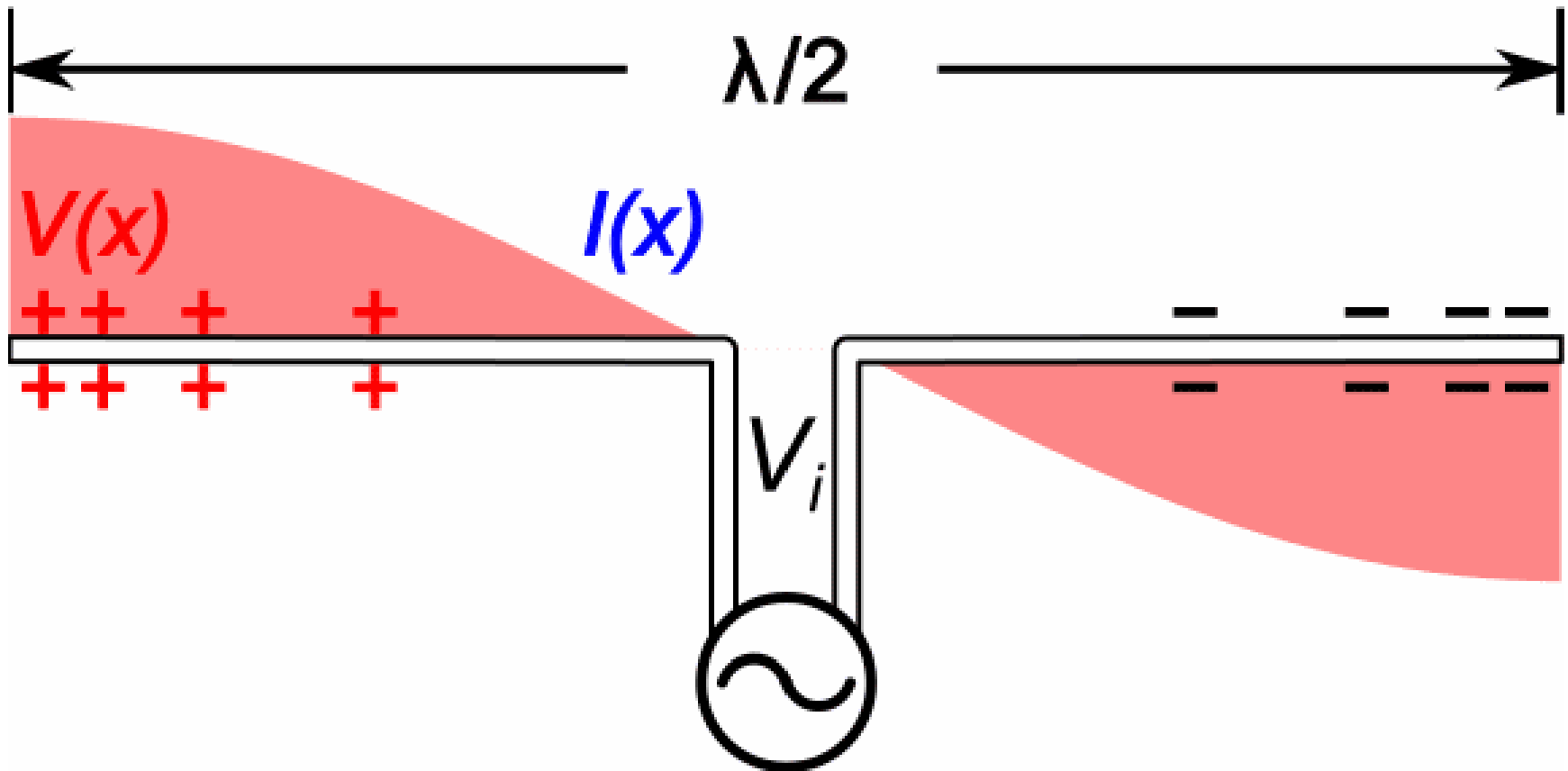


OCF Dipole



OCF Dipole

Antenna Voltage and Current Distribution





Feed Point Impedance

Dipole feed point impedance = 72Ω

Inverted V feed point impedance = 50Ω

Folded Dipole feed point impedance = 280Ω

OCF Dipole feed point impedance = $150 - 300 \Omega$

Slopped feed point impedance = 80Ω

Vertical Monopole feed point impedance = 36Ω

Antenna Modeling

- EZNEC

www.eznec.com



HAM Radio Board of Education
NEVER STOP LEARNING

**Next Session –
ARRL ANTENNA BOOK
Chapter 3
The Effects of Ground**

