Introduction to Antenna Basics

Week 3: Intro to Wire + Traveling Wave Antenna Design

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Housekeeping

Testing antennas without connectors

Open Source FEM software Elmer

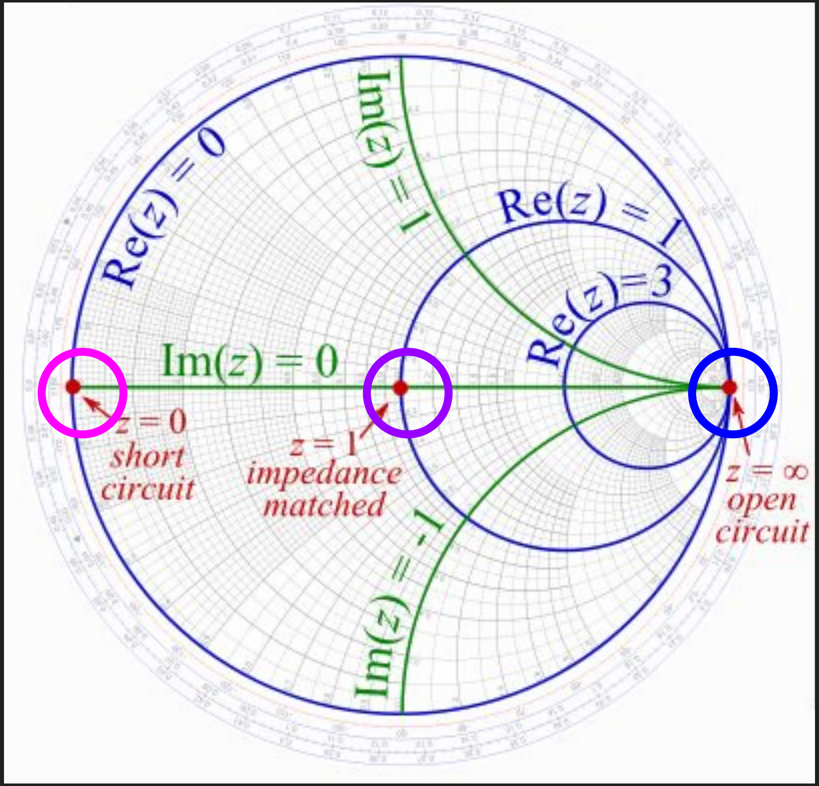
Recap from last class

Return loss (S11) is the ratio of reflected power to incident power

VSWR ranges from 1 to infinity

A short circuit is zero impedance, an open circuit is infinite impedance

Know where SOL is on a Smith chart



Week 3 Class Outline

Dipoles

Monopoles

Yagis

Baluns

Helixes

Before we begin…

You will need to tune your antenna

Prototype long and trim in small increments

Yes, even professionals have to tune

Half Wave Dipole

Gain: 2.15 dBi

points of maximum voltage are at the ends of the antenna

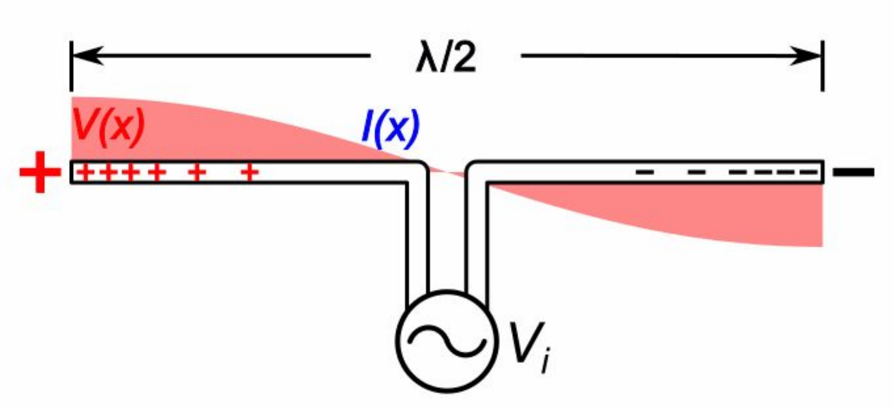
When a half wave dipole isn't a "half wave"

~0.96-0.98 a half wave

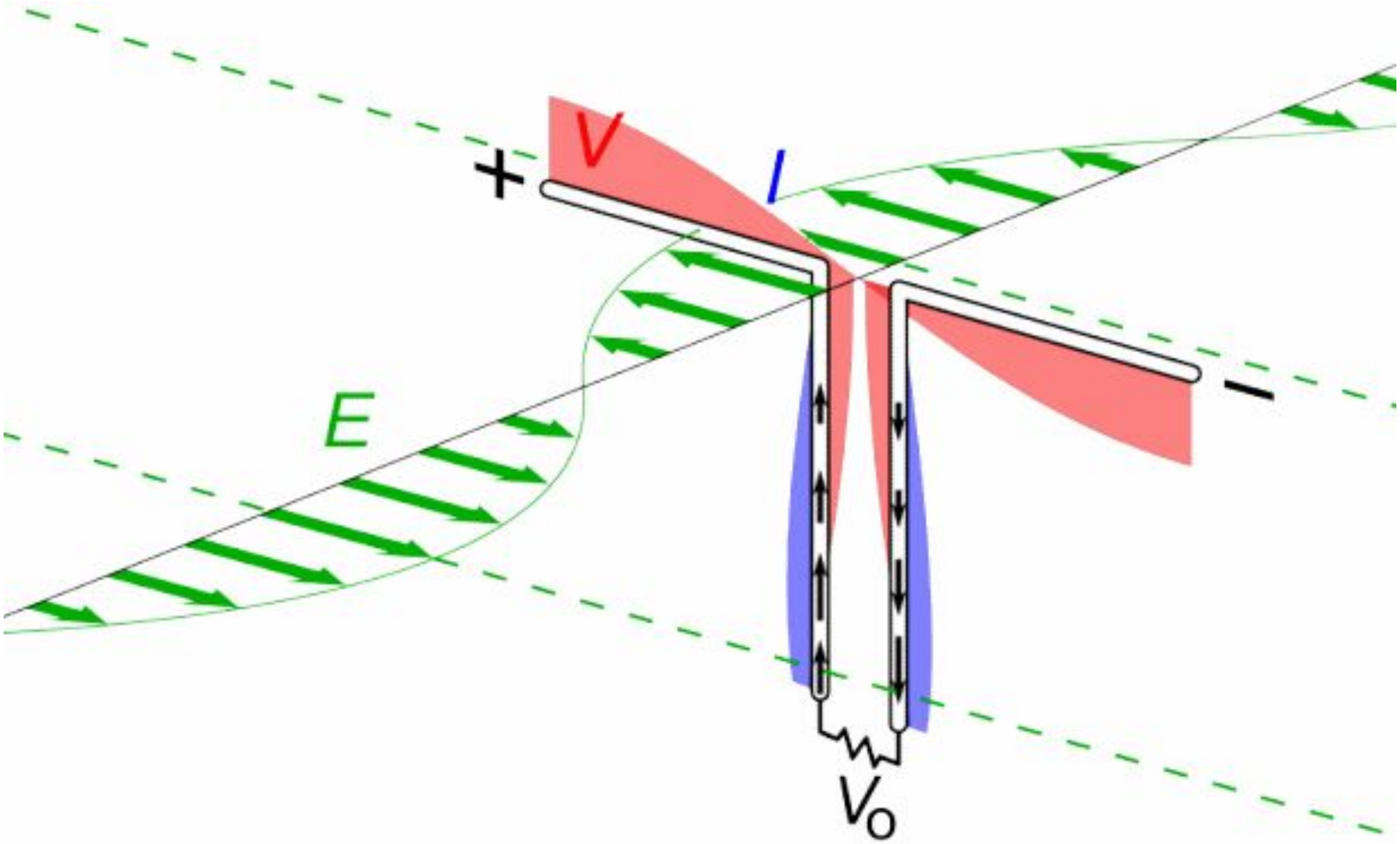
impedance for a half wave dipole antenna in free space is 73 Ω (good match to 70Ω coax)

Impedance depends on many factors!

Balanced antenna



Chetvorno, CC0, via Wikimedia Commons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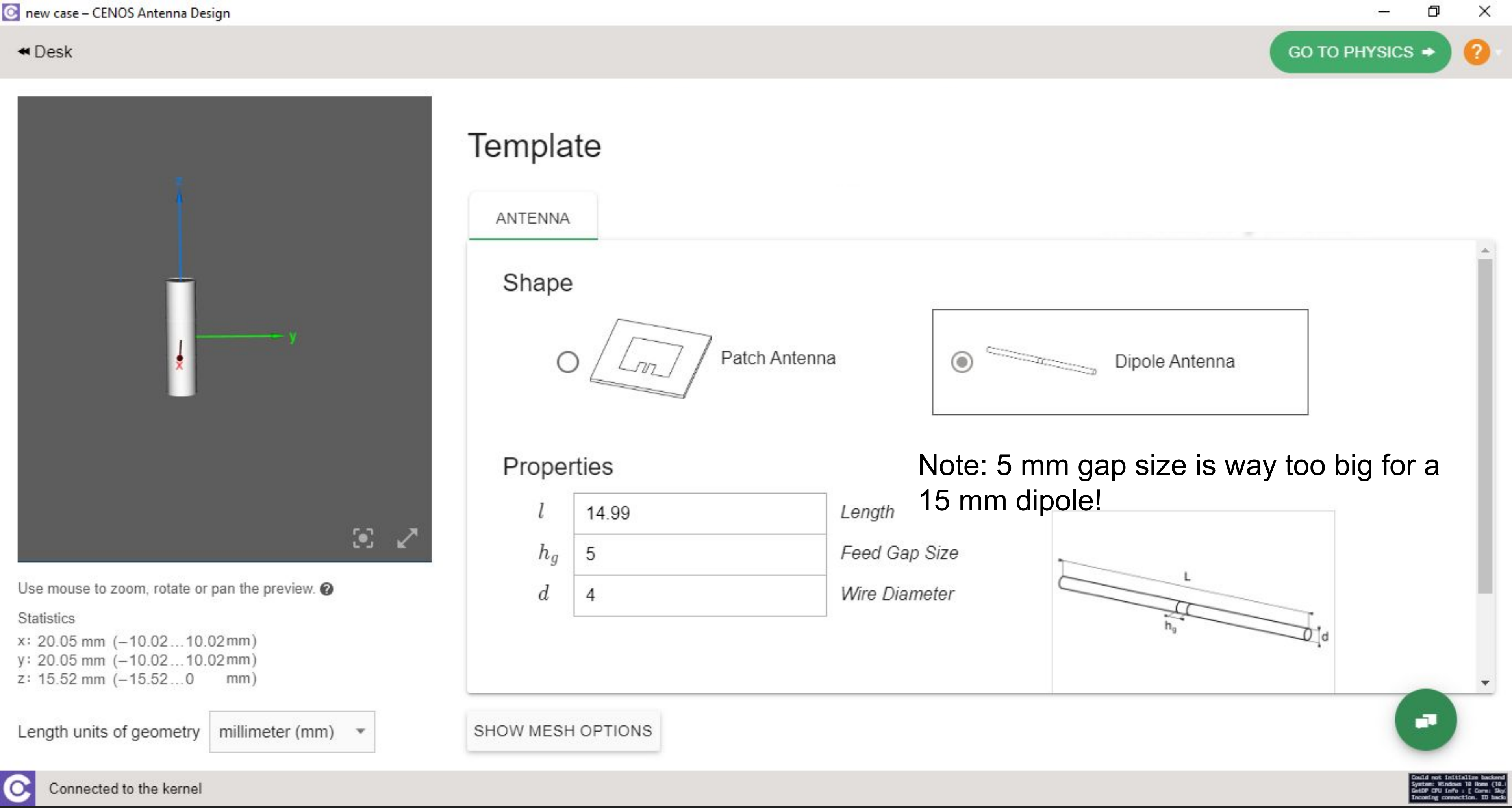
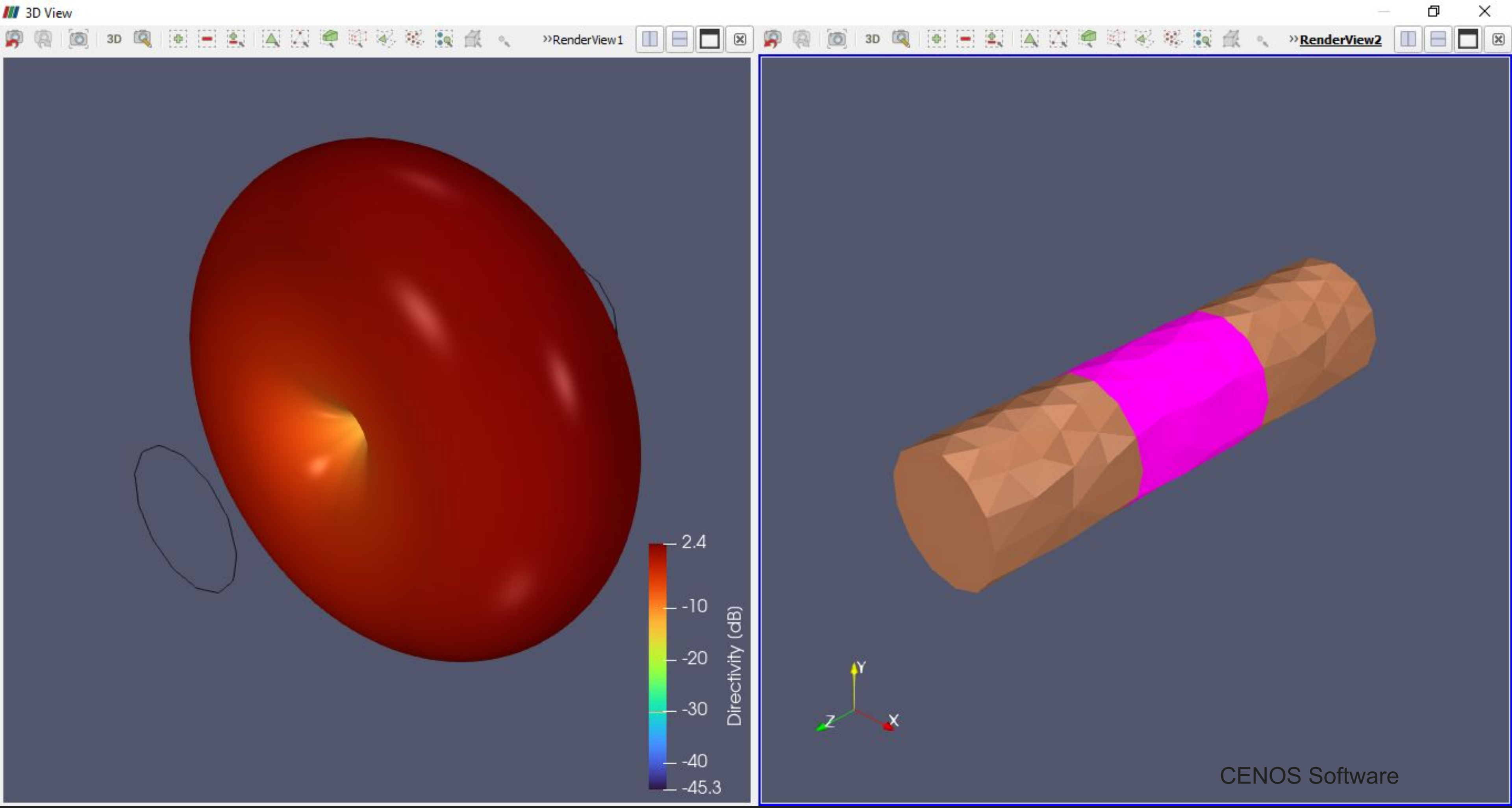
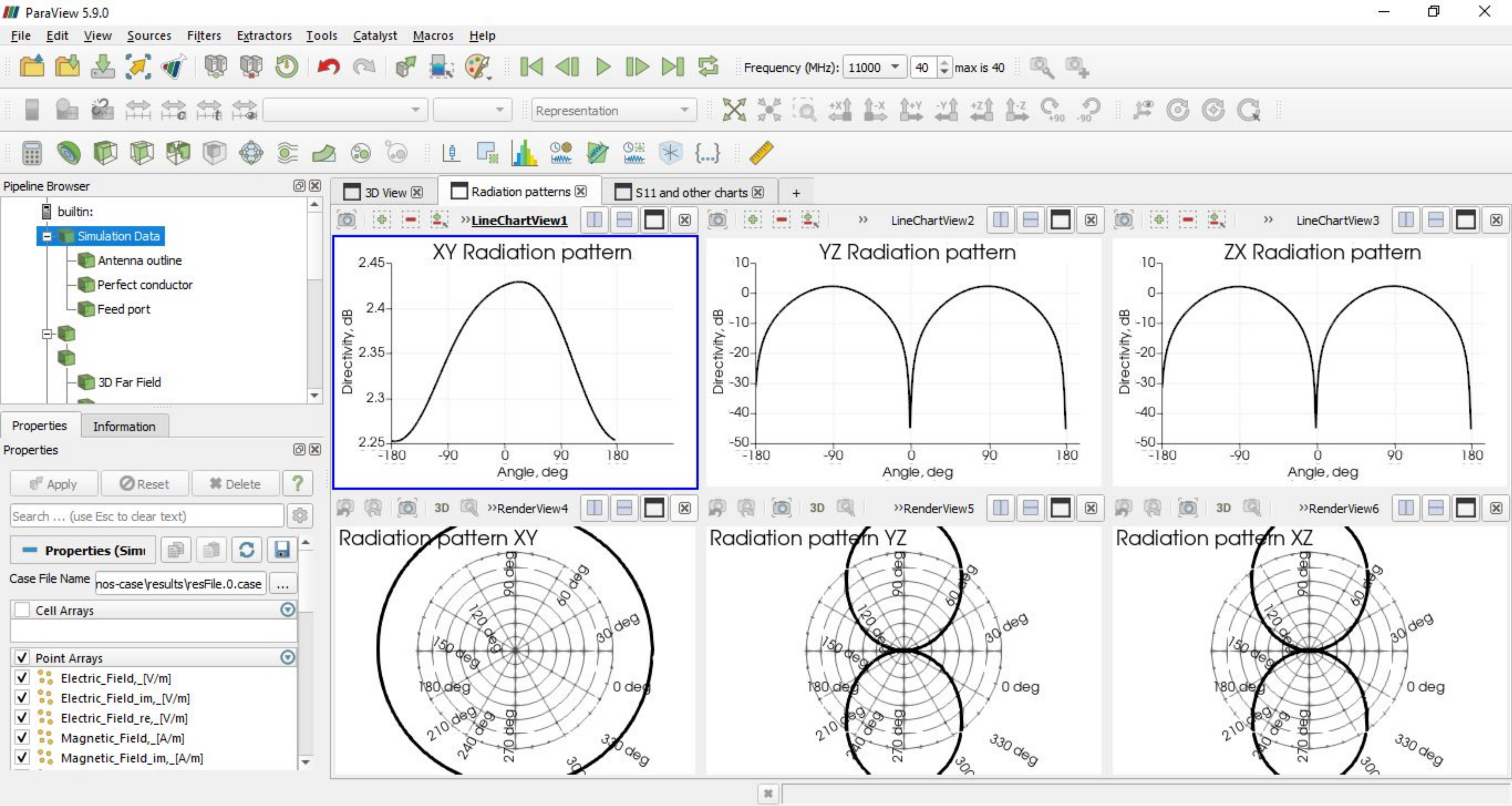


Note: 5 mm gap size is way too big for a 15 mm dipole!


3D View
RenderView1
RenderView2
2.4
-10
-20
-30
-40
-45.3
Directivity (dB)
Y
Z
X
CENOS Software


ParaView 5.9.0
File Edit View Sources Filters Extractors Tools Catalyst Macros Help
Frequency (MHz): 11000
40
max is 40
Representation
Pipeline Browser
builtin:
Simulation Data
Antenna outline
Perfect conductor
Feed port
3D Far Field
Properties
Information
Apply
Reset
Delete
Search ... (use Esc to clear text)
Properties (Simı
Case File Name
nos-case\results\resFile.0.case
Cell Arrays
Point Arrays
Electric_Field,_[V/m]
Electric_Field_im,_[V/m]
Electric_Field_re,_[V/m]
Magnetic_Field,_[A/m]
Magnetic_Field_im,_[A/m]
3D View
Radiation patterns
S11 and other charts
LineChartView1
LineChartView2
LineChartView3
XY Radiation pattern
YZ Radiation pattern
ZX Radiation pattern
Directivity, dB
Angle, deg
RenderView4
RenderView5
RenderView6
Radiation pattern XY
Radiation pattern YZ
Radiation pattern XZ
0 deg
30 deg
60 deg
90 deg
120 deg
150 deg
180 deg
210 deg
240 deg
270 deg
330 deg

Monopoles

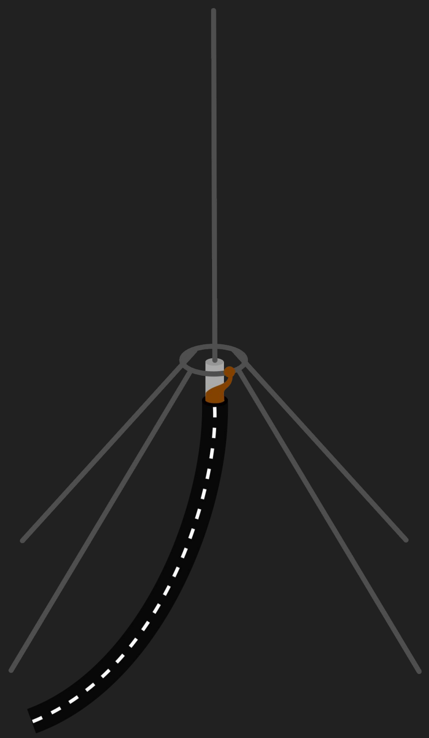
monopole antenna is one half of a dipole antenna, almost always mounted above some sort of ground plane

Most common: ¼ wave monopole

Typical gain 2-3 dBi

omnidirectional radiation pattern

Vertically polarized



Chetvorno, CC0, via Wikimedia Commons

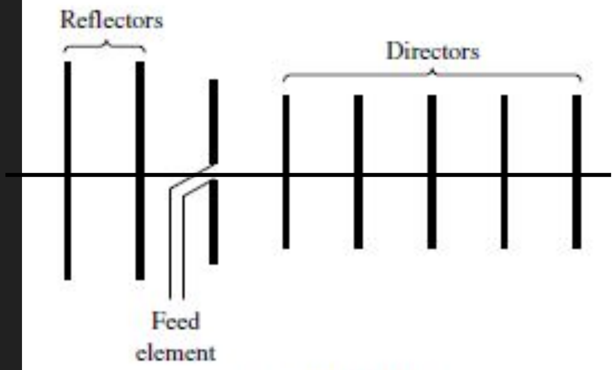
Yagi Antennas: Pros and Cons

Pros

- high gain ~9 dB
- high front to back ratio
- cheap
- lightweight

Cons

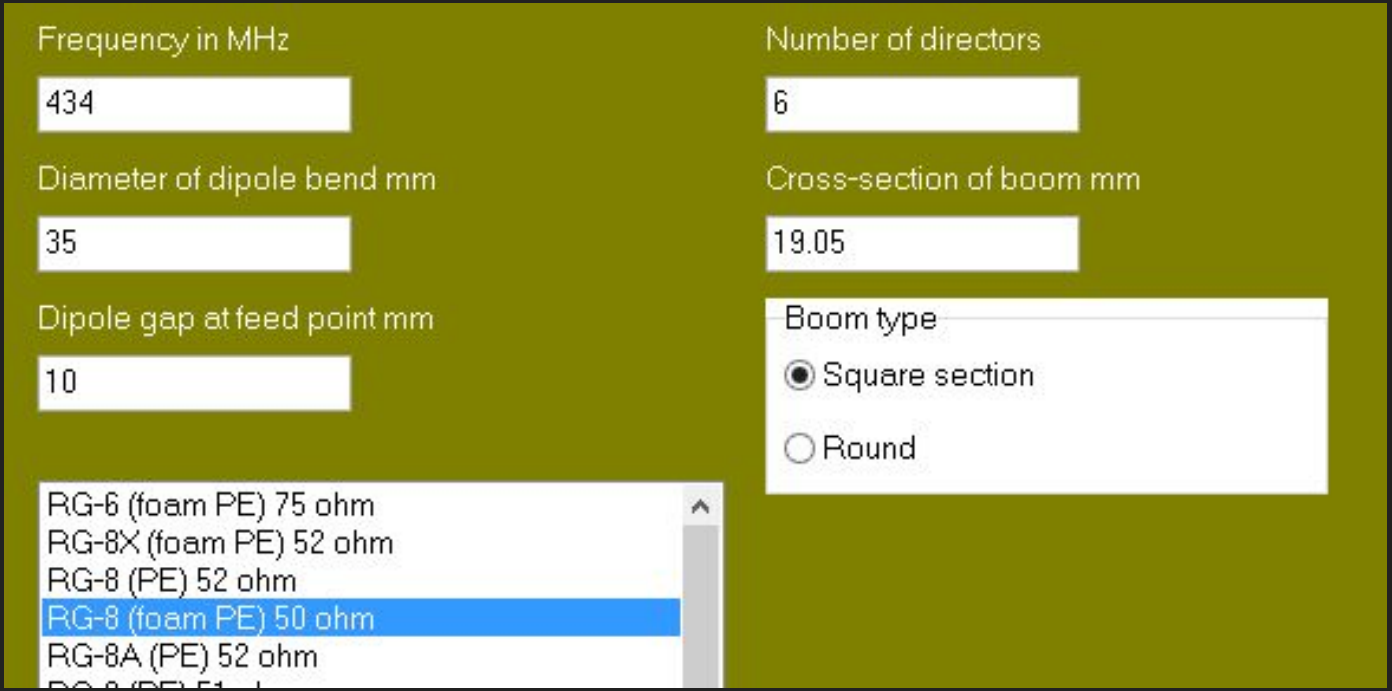
- for high gain, the antenna becomes very long
- gain limitation ~ 20 dB
- must take care to avoid measurement/machining errors above HF



(a) Yagi-Uda array

Image Source: Antenna Theory, Balanis

Calculator Input



Software Shown: VK5DJ Yagi Calculator

Director Calculated Output

Design - 434 MHz Yagi [70 cm (420 to 450 MHz) band]

DIRECTORS

Dir (no.)	Length (mm)	Spaced (mm)	Boom position (mm)	IT (mm)	Gain (dBd)	Gain (dBi)
1	306.8	51.8	220.0	144.0	4.8	6.9
2	303.2	124.3	344.3	142.0	6.5	8.6
3	299.8	148.5	492.8	140.5	7.8	9.9
4	296.7	172.7	665.5	139.0	8.9	11.0
5	293.8	193.4	858.9	137.5	9.8	11.9

Software Shown: VK5DJ Yagi Calculator

Design Methodology Comparison

	Antenna Theory Book (mm)	**VK5DJ Yagi Calculator (mm)**	**Delta (%)**
Reflector	0.48λ = 332	348	4.6
Director 1	0.428λ = 296	307	3.6
Director 2	0.424λ = 293	303	2.3
Director 3	0.428λ= 296	300	1.3
Director 4	(0.428-0.398)λ=296-275	297	
Director 5	(0.407-0.428)λ=281-296	294	

Design Output

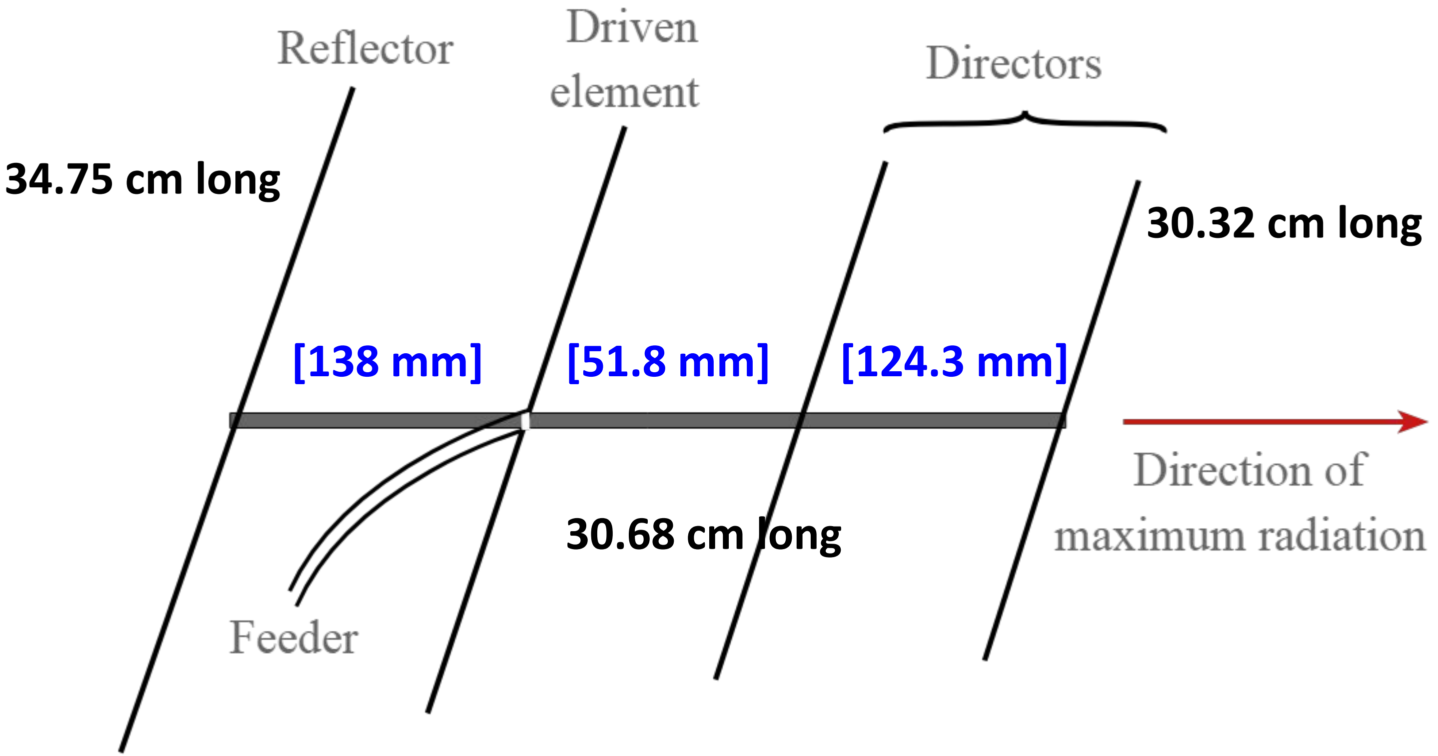


Image Source: https://www.electronics-notes.com/articles/antennas-propagation/yagi-uda-antenna-aerial/basics-overview.php

Driven Element: λ/2 folded dipole

- Same gain and radiation pattern for folded dipole as single-wire
- Most critical dimension seems to be the overall length
- 2nd most important dimension: tubing diameter
  - both of these are less critical for a folded dipole than for a plain rod dipole or yagi directors
- Spacing between the two arms of the 'trombone' can vary between quite wide limits
- ZA=4*Zd. Impedance of a half-wave dipole antenna is approximately 70 Ohms, so that the input impedance for a half-wave folded dipole antenna is roughly 280 Ohms.

Source:
http://www.w9dup.org/technet_files/folded_dipoles_vhf_uhf_yagis.pdf

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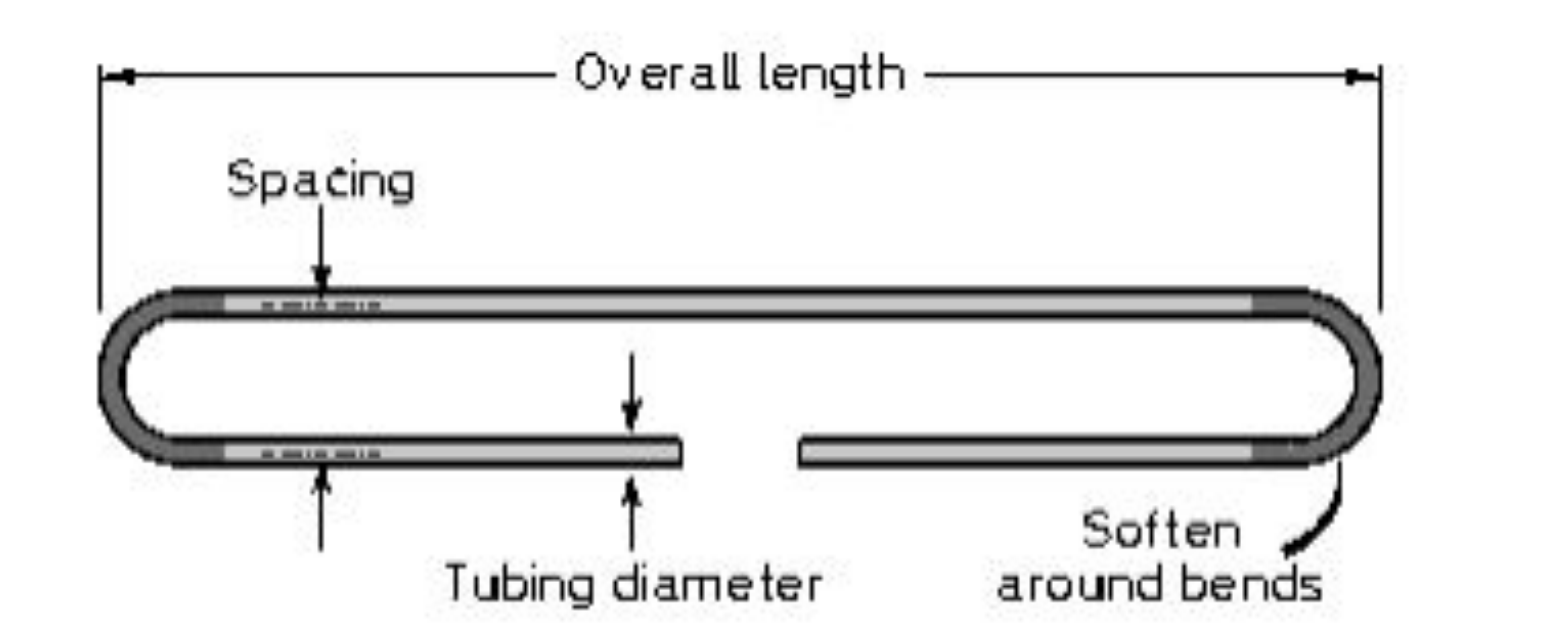

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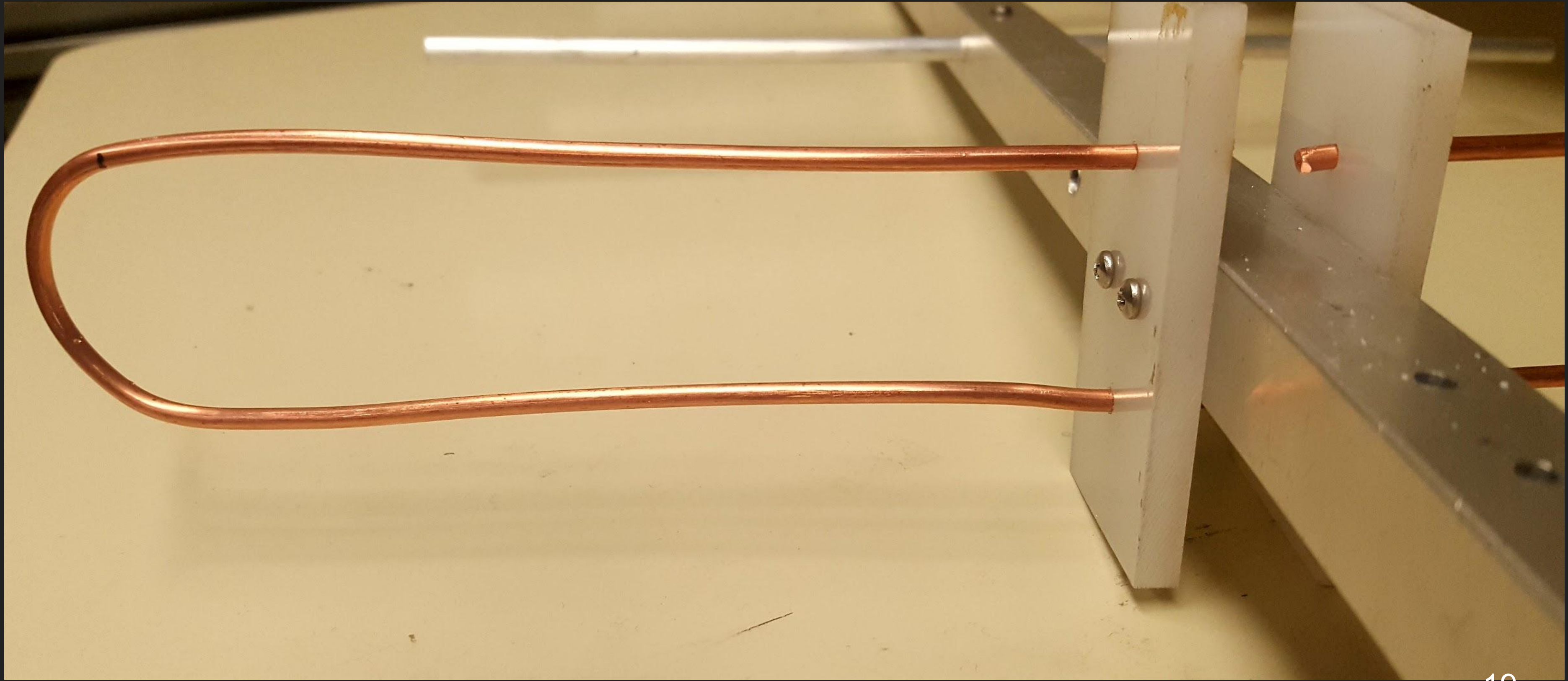


Baluns

Balun = balanced to unbalanced

an electrical device that converts between a balanced signal (antenna) and an unbalanced signal (coax)

Can be 1:1 just for balanced to unbalanced transform

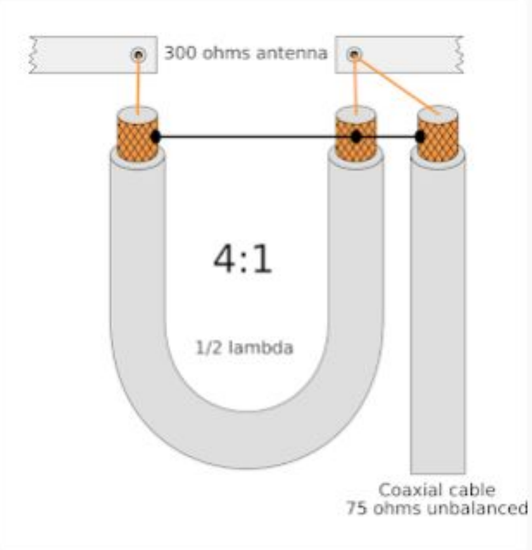
Can be used for impedance matching (4:1 example)

λ/2 4:1 balun

- Impedance matching
  - can be used as well for 300 to 75 ohms matching, but also for 200 to 50 ohms
- Length = λ/2* velocity factor of coax
  - Velocity factor found on data sheet
  - 434 MHz example: (69.1 cm)/2 * 0.85 = 29.4 cm

Source: https://www.onetransistor.eu/2018/04/transmission-line-baluns-for-vhf-and-uhf.html

Balun Approach



4:1 balun with half-wavelength cable

This 4:1 balun can be used as well for 300 to 75 ohms matching, but also for 200 to 50 ohms. The centre cores of the half wavelength piece of cable connect to the terminals of the dipole. The feeder cable centre connects to one of the terminals of the dipole (it doesn't matter which one). The ground shields from all cable ends connect together.

Source: https://www.onetransistor.eu/2018/04/transmission-line-baluns-for-vhf-and-uhf.html

Balun Calculation

Here we calculate the half wave length of the matching section of the 4:1 coax balun. Again the equations are taken from the ARRL Antenna Book.

Output Values

Half Lambda Coax Matching Section Length (Ft.) = 0.9632027649769586
Half Lambda Coax Matching Section Length (In.) = 11.558433179723503

11.56 inches = 29.36 cm

Input Values

Change the value, move the cursor to empty space and click to re-calculate.

Frequency (MHz) = 434
Velocity Factor (decimal percent) = 0.85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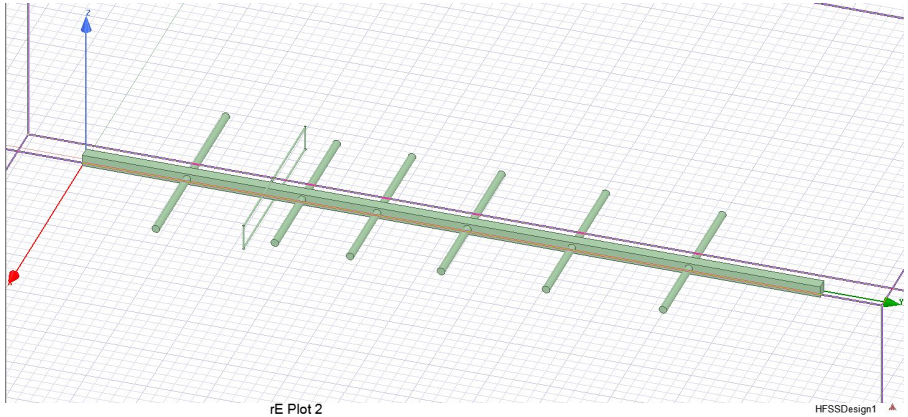
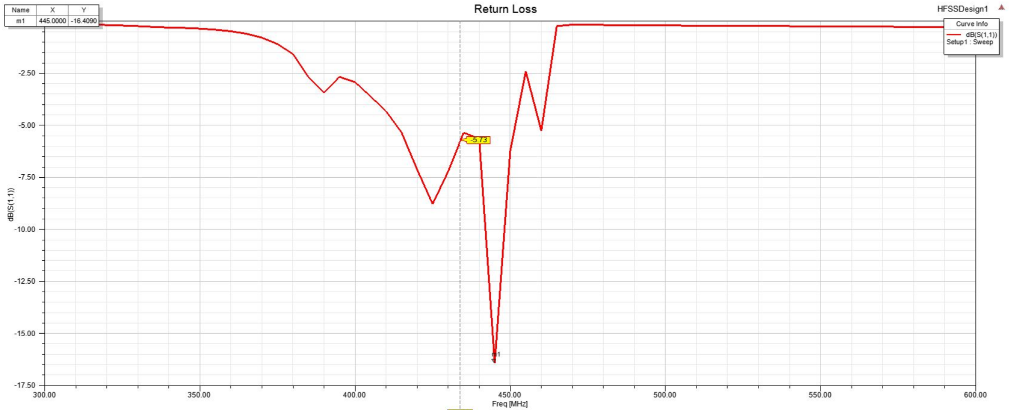
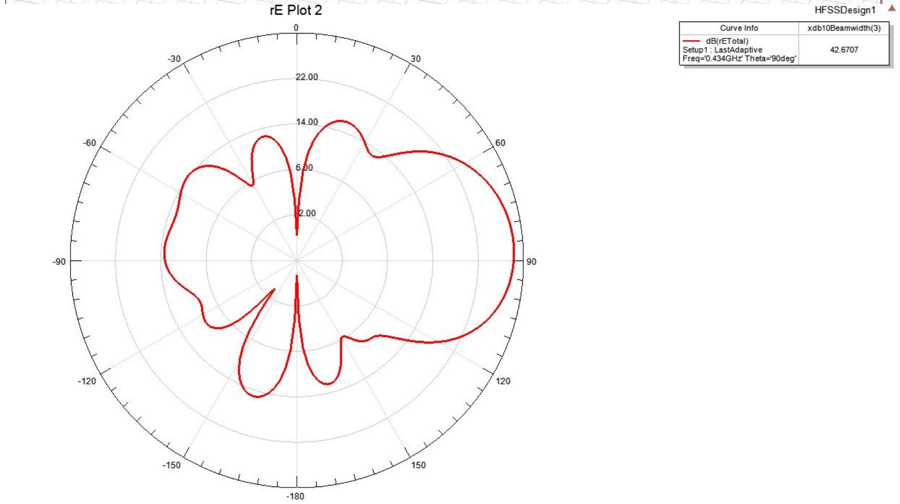
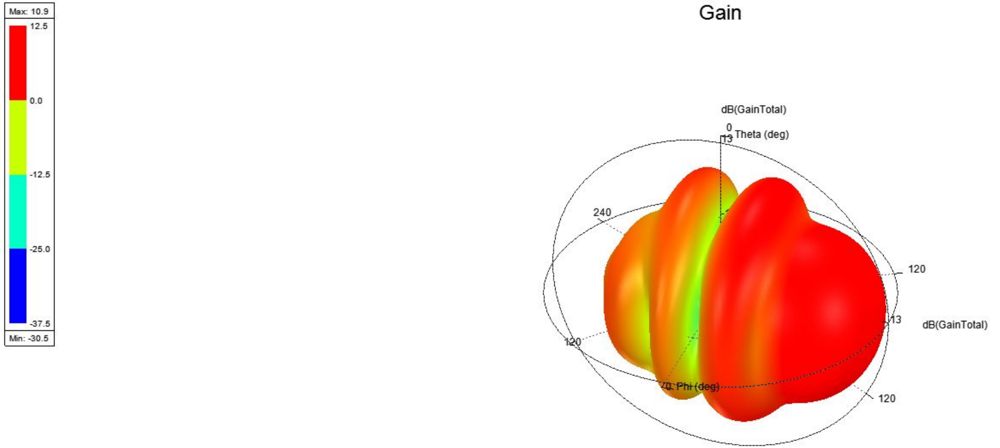
HFSS Model + Simulation Results



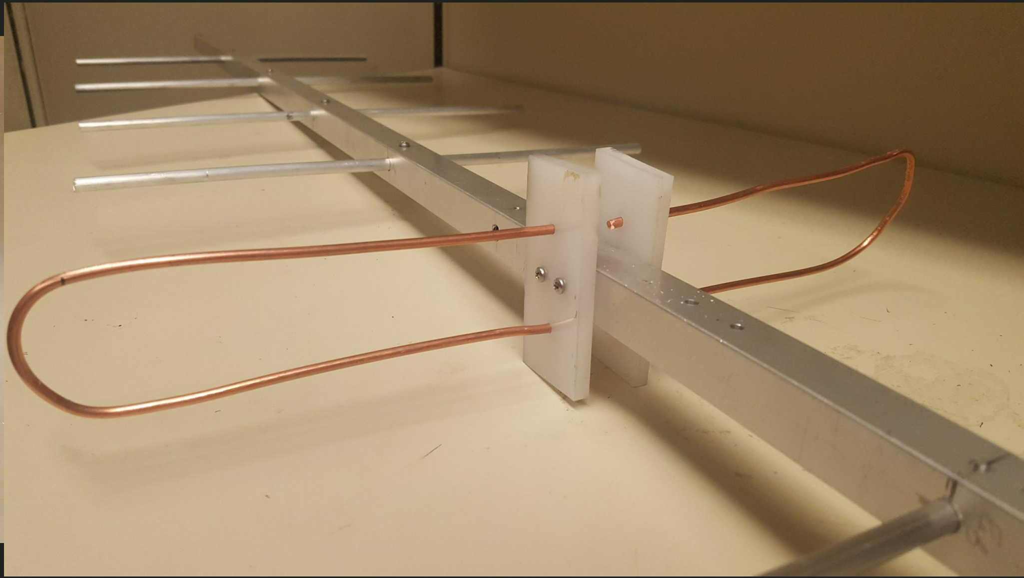






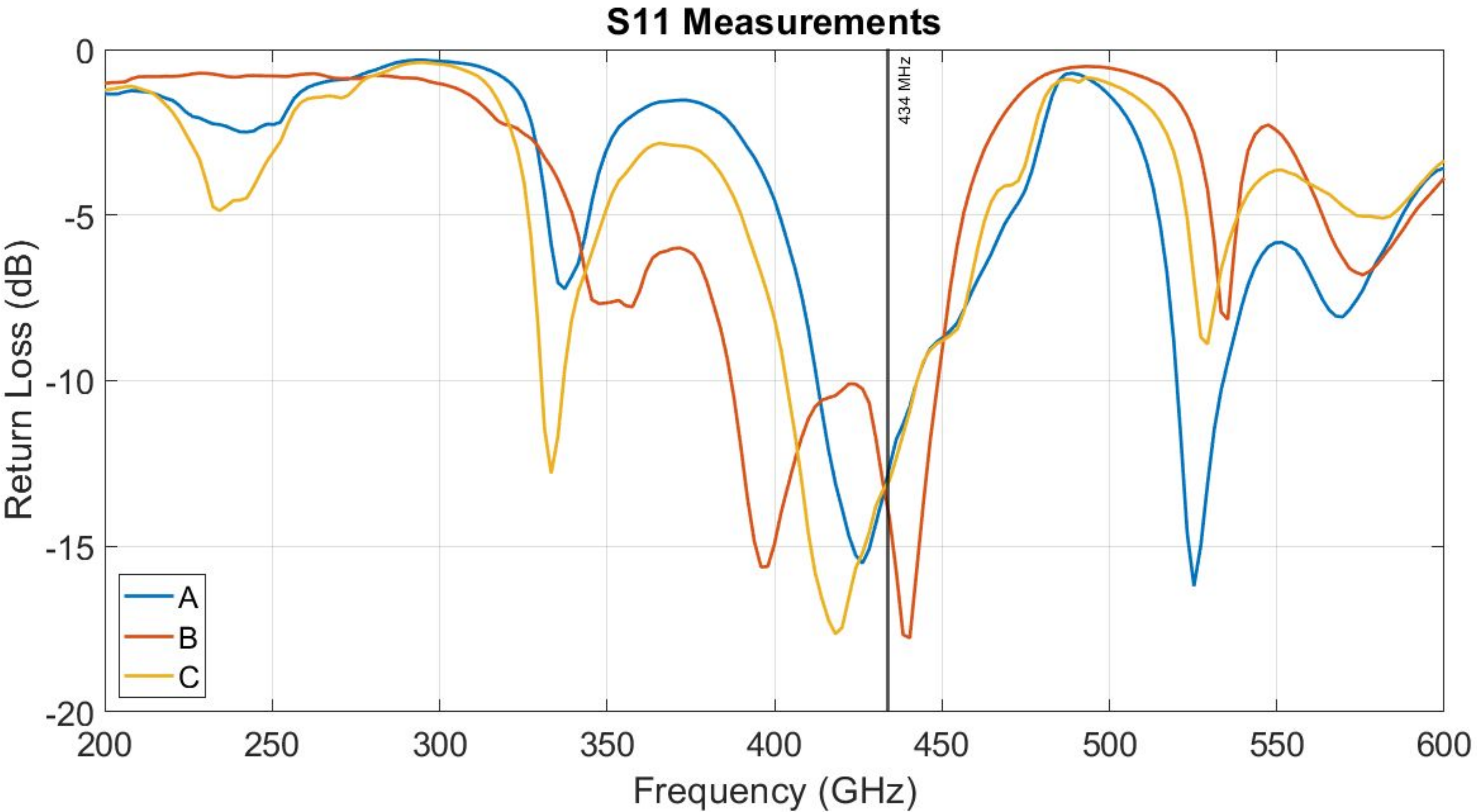
Built Yagi

Parasitic Elements Only



½λ Folded Dipole

S11: All Built Yagi Models



Helix (helical) antennas

Great for circular polarization!

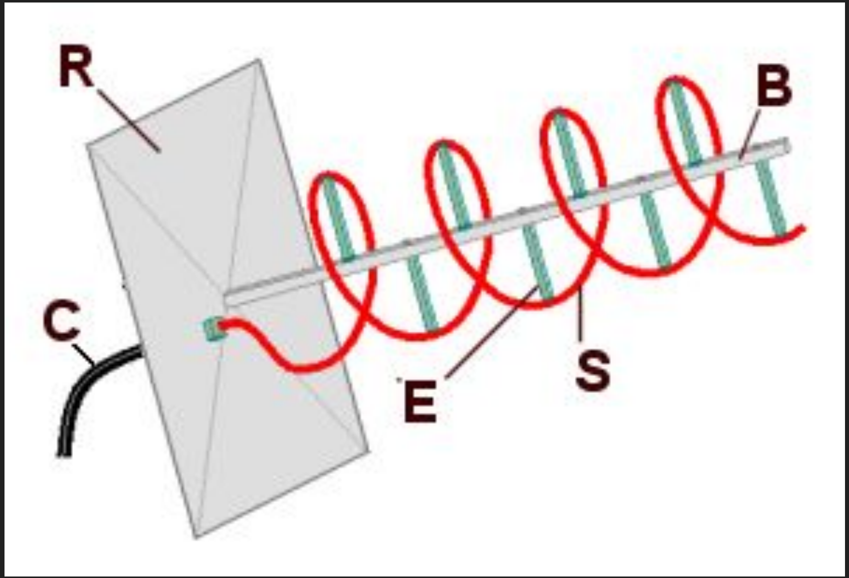
(B) Central support,

(C) Coaxial cable feedline,

(E) Insulating supports for the helix,

(R) Reflector ground plane,

(S) Helical radiating wire



Varieties of Helix Antennas

Monofilar: one helical wire

Bifilar, or quadrifilar: two or four wires in a helix

Directional helical antennas are mounted over a ground plane

Broadside vs end-fire

- Broadside monofilar designs - linearly polarized parallel to the helix axis
- Broadside bifilar or quadrifilar - broadside circularly polarized radiation
- End-fire - circularly polarized

3D Printing Ideas - Helical Antenna Frame

Directional, end-fire

Shown:

- RHCP, 5.8GHz, ~10dBi gain

Tendency to bend -

- Use higher infill and caution

Image: https://www.thingiverse.com/

Resources

[Half Wave Dipole Antenna](#)
[Dipole Antenna Length: calculation & formula](#)
[Yagi Calculator by John Drew VK5DJ](#)
[4:1 Balun calculator](#)
[Transmission line baluns for VHF and UHF](#)
[Folded Dipoles for VHF/UHF Yagis](#)
[Customizable Helix (Helical) Antenna Frame and Winding Template](#)
[Helical antenna design calculator](#)

Coming up next class

Introduction to planar antenna design. Topics covered will be, but are not limited to: slots, patches, and vivaldis.

Questions?