

HF Wire Antennas

From Spool to Sky

Presentation to Cabarrus ARS – July 2026



AI2F, Christopher S. Krstanovic, Ph.D – Member ARRL, CARS, RARS

Copper is the best amplifier!

The antenna is the most important part of any radio station

Presentation Goals:

- ✓ Cover Basic HF Wire Antenna Types
- ✓ Only resonant, “no tuner” antennas that you can build
- ✓ Help you chose appropriate solution for your goals and situation
- ✓ Not a DIY build manual, plenty info on-line

What we will Cover:



Antenna Basics

Dipole and Derivatives

Verticals

Loops

Antennas for HOA / Restricted
Properties

Antenna Construction Materials

Tools



What Makes a Good Antenna?

- Efficiency
- Radiation Pattern – Predictable and Low Angle
- Band coverage
- Mechanical reliability
- Cost
- Ease of installation

Antenna Myths:

- "Low SWR means a good antenna"
- "Any wire works"
- "The tuner fixes everything"
- "Verticals don't need radials"

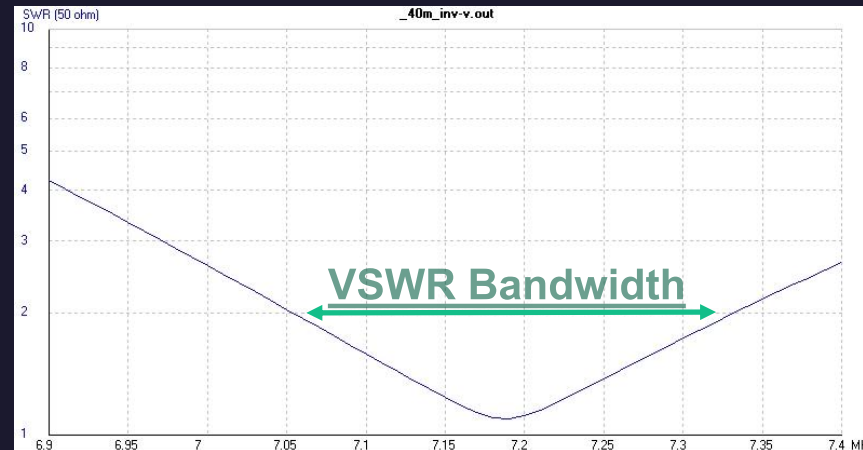
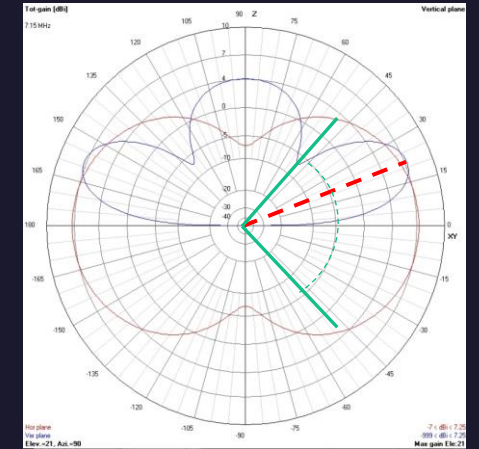


Ideal Antenna?

The “best” antenna is the one that radiates the most power in the direction you need, at the elevation angle you need, from the space you actually have.

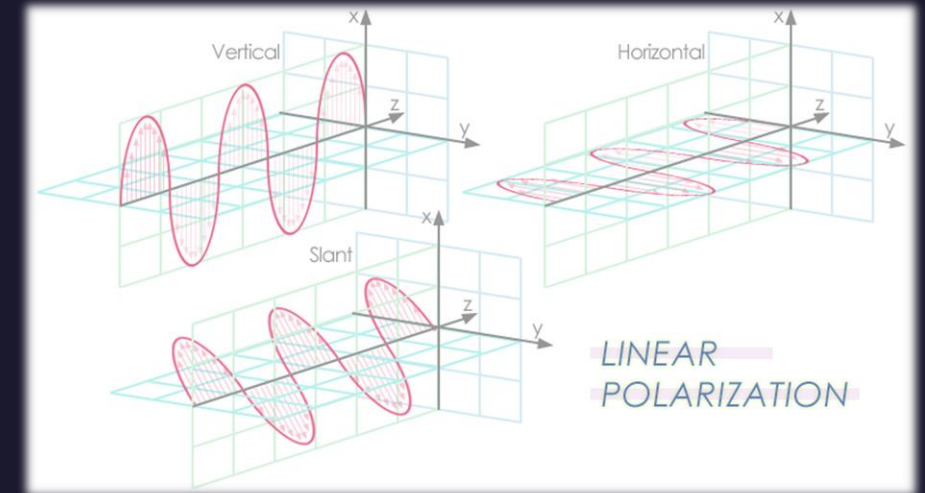
Key Antenna Parameters

- Resonance
- Efficiency
- Bandwidth (VSWR and Efficiency)
- Gain (at height and elevation)
- Feed-point impedance
- Radiation pattern (el / bw)
- Polarization



Antenna Polarization

- Orientation of the antenna's electric field
- Horizontal dipole produces horizontal polarization
- Vertical antenna produces vertical polarization
- On HF bands ionosphere randomizes polarization
- Verticals have lower launch angle but higher QRN
- Horizontals have higher gain, but need height
- Chose antenna based on desired radiation pattern and gain.



Basic HF Wire Antenna Types

Dipole and Derivatives

Most common on HF
Simple and Cheap
Decent Performers

Loops

Very Quiet on RX
Very Good Performers
Multiband with Tuner

Verticals

Not a limited space
Antenna!
Low Radiation Angle
Low Peak Gain
Higher Noise

Wire Beams

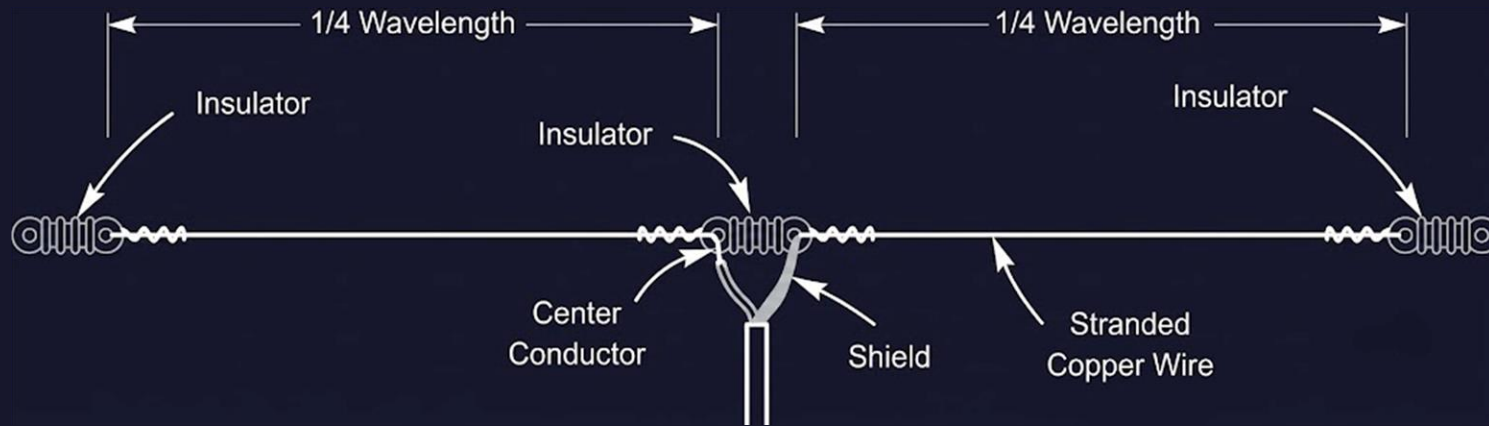
Excellent Performers
Nice F/B
Need Rotators and Support
DIY Options readily
Available
Can be made for ~\$150

Dr. Strangelove Stuff

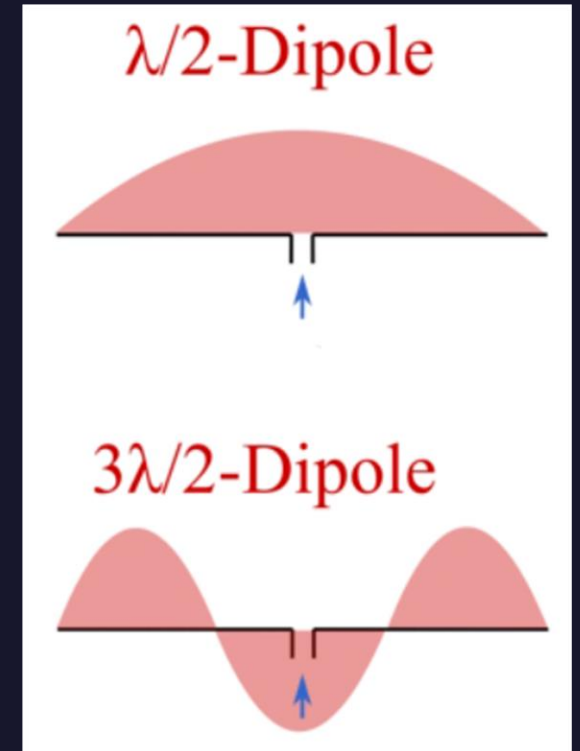
Necessity is Mother of Invention
Antennas of Last Resort (HOA...)
May not work in your installation
Look to RSGB for ideas



Dipole - The Foundation Antenna



- Resonant on one band (also on 3rd, 5th... overtones)
- Feed-point impedance $\sim 72\Omega$ in free space
- Predictable performance
- Simple and inexpensive
- Truly Foundational - Many variations
- Excellent first HF antenna: Easy to build, Efficient



Antenna Height

Height Often Matters More Than Antenna Type

- Height of HF antenna affects its pattern & take-off angle
- Height is measured in wavelengths (λ), not feet!
- Antennas below $\frac{1}{4} \lambda$ radiate mostly straight up
- **At $\frac{1}{2} \lambda$ + antennas develop excellent low-angle radiation**
- Above 1λ multiple radiation lobes and nulls appear
- Increasing antenna height improves DX performance

Horizontal Dipole

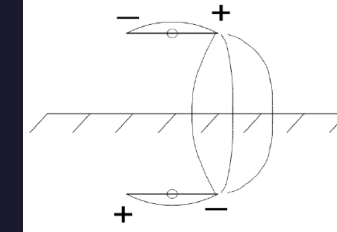


Image has
opposite phase

Vertical Dipole

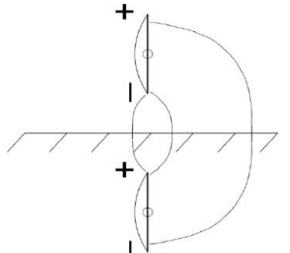
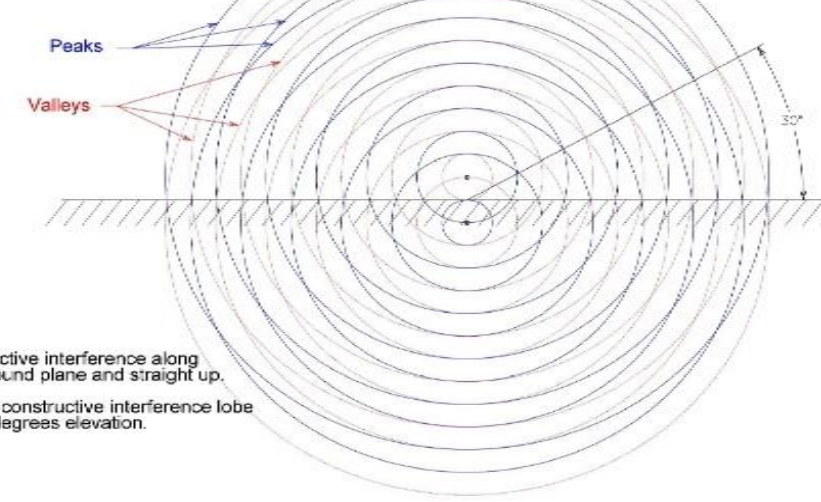


Image has
same phase

Horizontal Dipole Over Ground
 $\frac{1}{2}$ Wavelength High



Sidebar: Where does DX Come From?

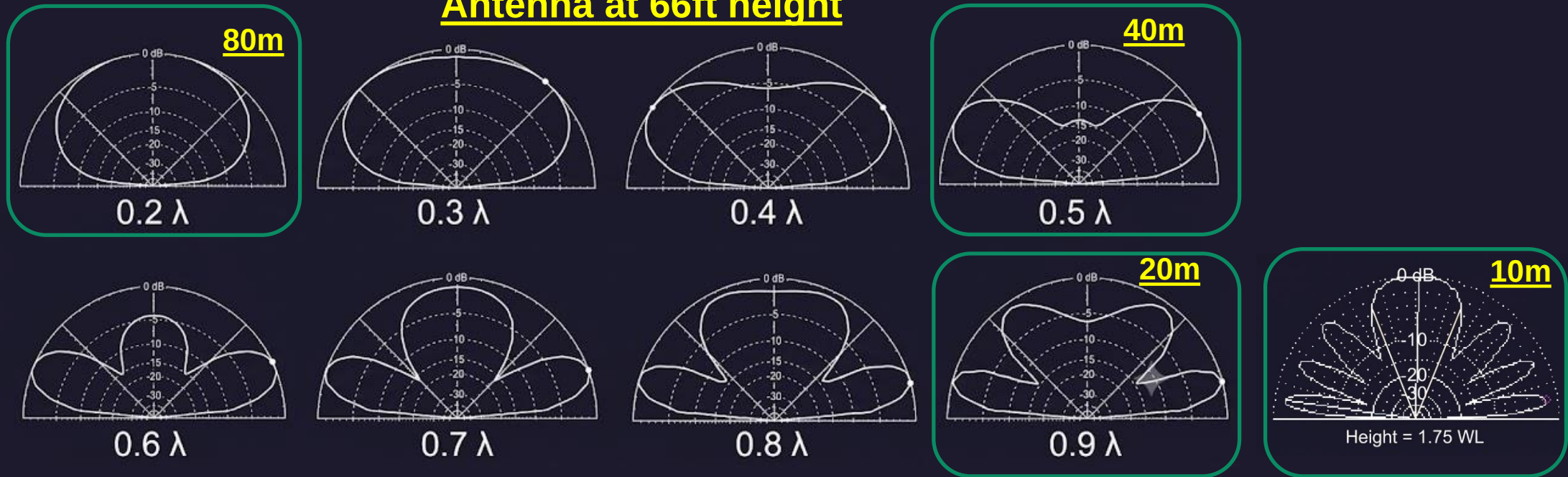
Frequency Band	"Core" DX Angle Range	Typical Average Angle	Long-Path Angle
80 Meters (3.5 MHz)	8° — 18°	~12°	As low as 5°
40 Meters (7 MHz)	6° — 16°	~10°	As low as 3°
30 Meters (10.1 MHz)	5° — 14°	~8°	As low as 2°
20 Meters (14 MHz)	4° — 12°	~6°	As low as 1°
17 Meters (18 MHz)	3° — 10°	~5°	As low as 1°
15 Meters (21 MHz)	3° — 9°	~5°	As low as <1°
12 Meters (24.9 MHz)	2° — 8°	~4°	As low as <1°
10 Meters (28 MHz)	2° — 7°	~4°	As low as <1°



Dipole* Height Radiation Patterns

- Above 0.5λ lowers take-off angle, but radiates more vertical power
- Below 0.3λ is good for NVIS, or warming clouds.

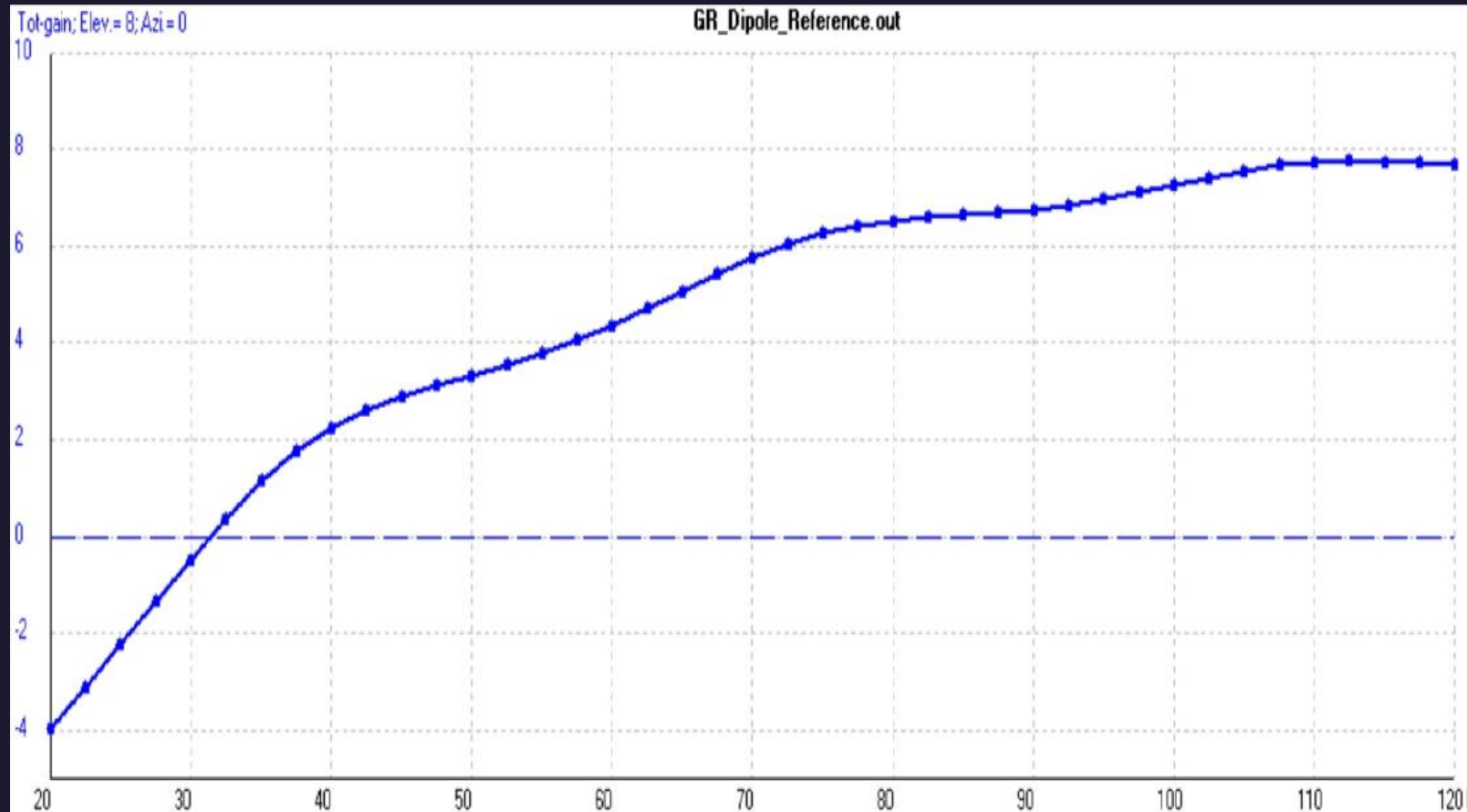
Antenna at 66ft height



A mediocre antenna at a good height will outperform an excellent antenna installed too low, but there is also such thing as too high!

Dipole Antenna DX Gain

Horizontal 20m Dipole Gain at 8 deg elevation



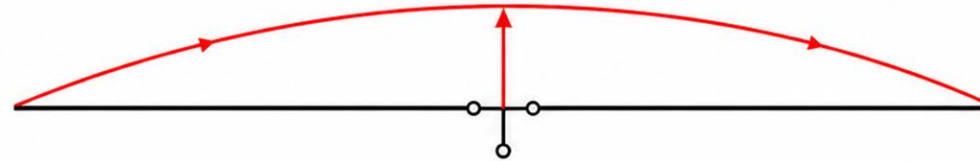
Height in feet



Dipole Harmonic Resonances

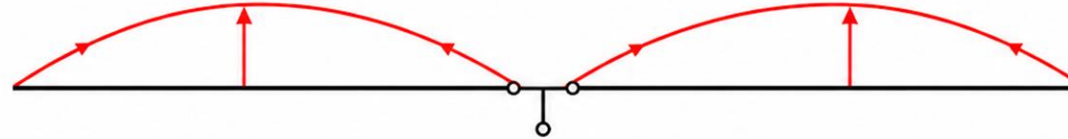
CURRENT DISTRIBUTION ON A CENTER FED DIPOLE – FIRST 5 HARMONICS

1st HARMONIC
(Fundamental)
Length = $\frac{1}{2} \lambda$



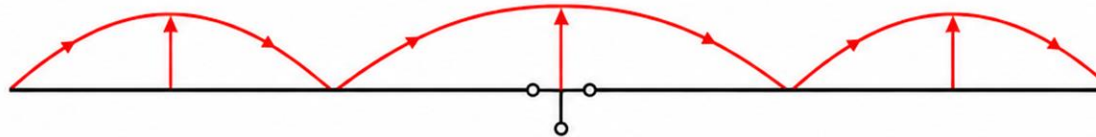
One half-wave
Current maximum
at center
Zero at ends

2nd HARMONIC
Length = λ



One full-wave
Current maximum
at 1/4 and 3/4 points
Zero at center and ends

3rd HARMONIC
Length = $\frac{3}{2} \lambda$



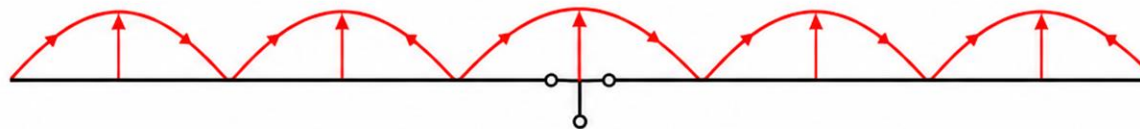
One and a half waves
Current maximum
at 1/6, 1/2, 5/6 points
Zero at 1/3, 2/3 and ends

4th HARMONIC
Length = 2λ



Two full waves
Current maximum
at 1/8, 3/8, 5/8, 7/8 points
Zero at center, 1/4, 3/4 and ends

5th HARMONIC
Length = $\frac{5}{2} \lambda$



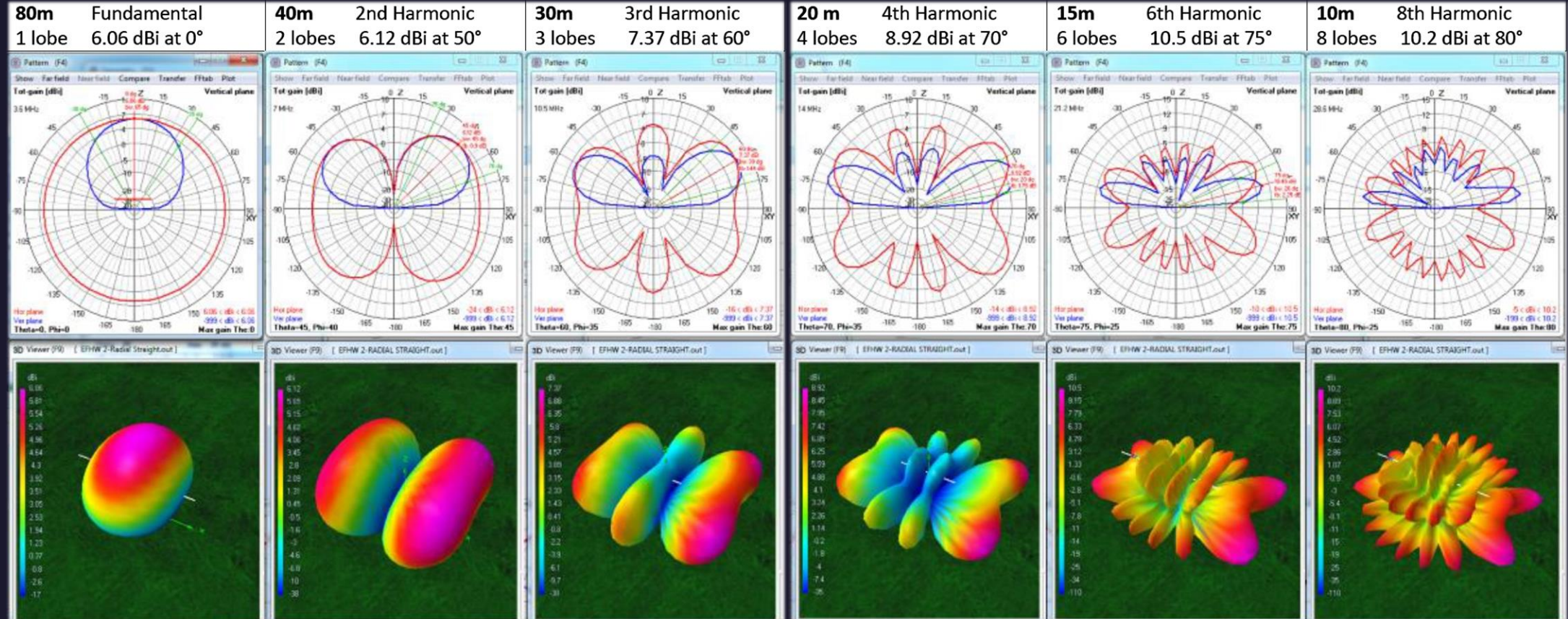
Two and a half waves
Current maximum
at 1/10, 3/10, 1/2, 7/10, 9/10 points
Zero at 1/5, 2/5, 3/5, 4/5 and ends

— Red line: Current magnitude (relative)

→ Arrow: Direction of conventional current

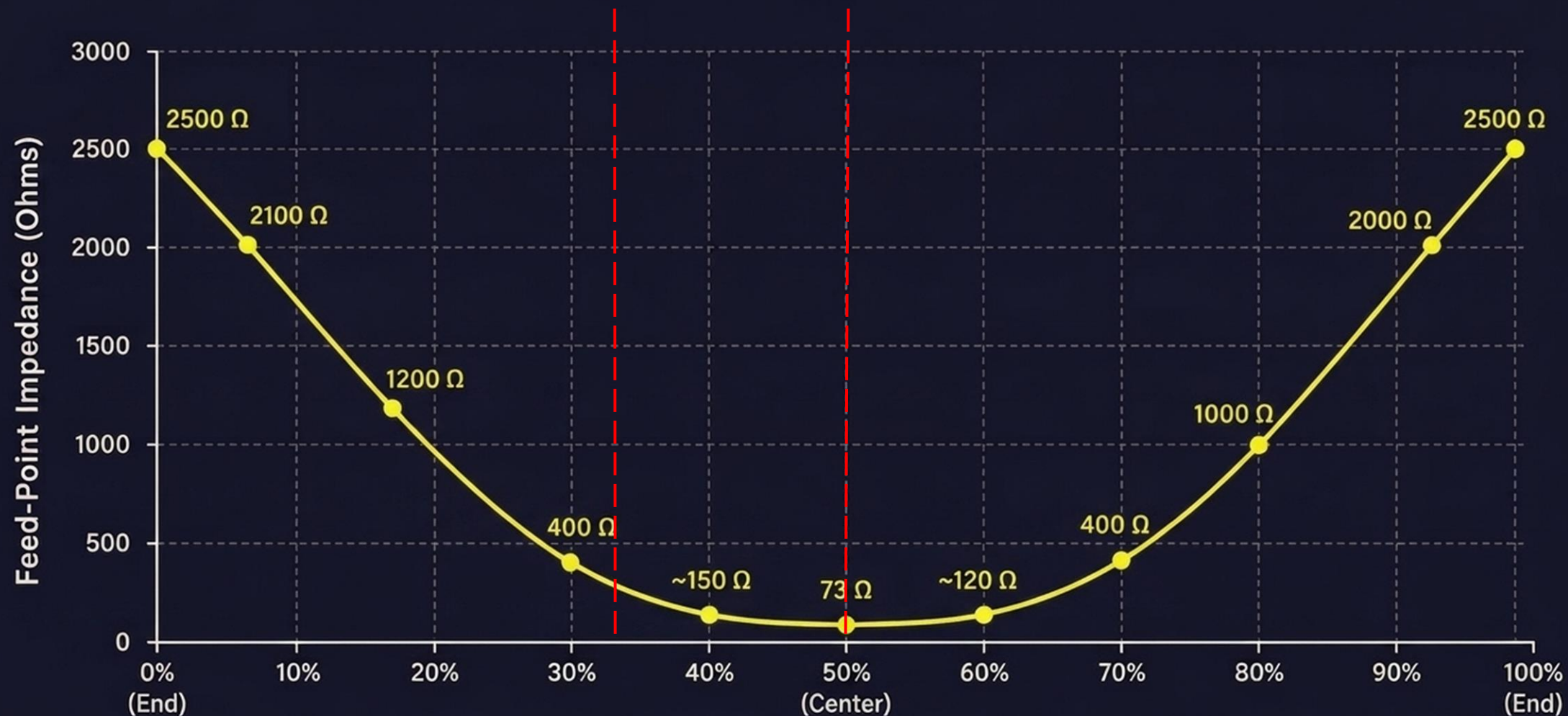
Dipole* Harmonic Radiation Patterns

At 60 feet height

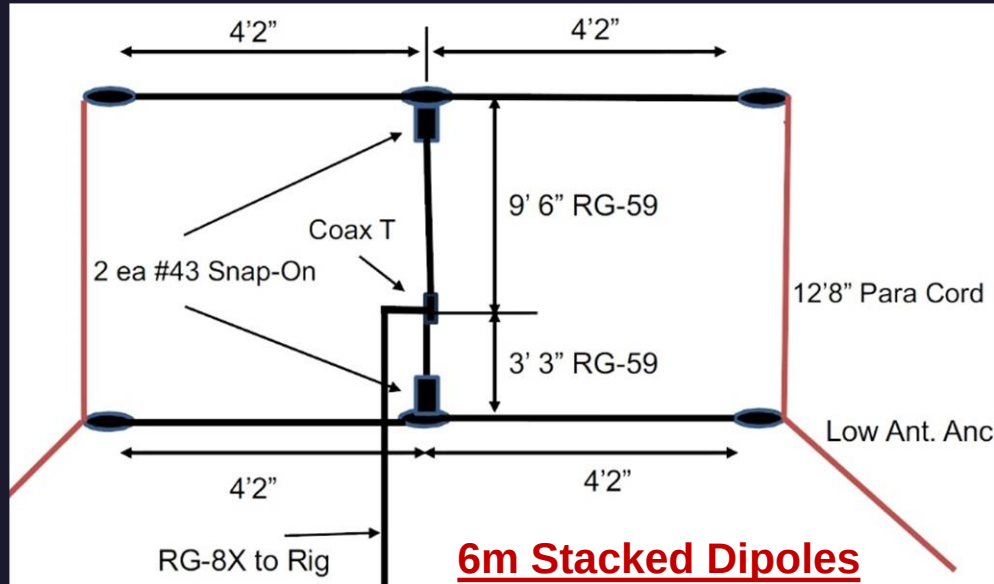


Dipole Feed-Point Impedance vs. Full Dipole Location

(Idealized Half-Wave Dipole in Free Space - Illustrative Symmetric Curve)

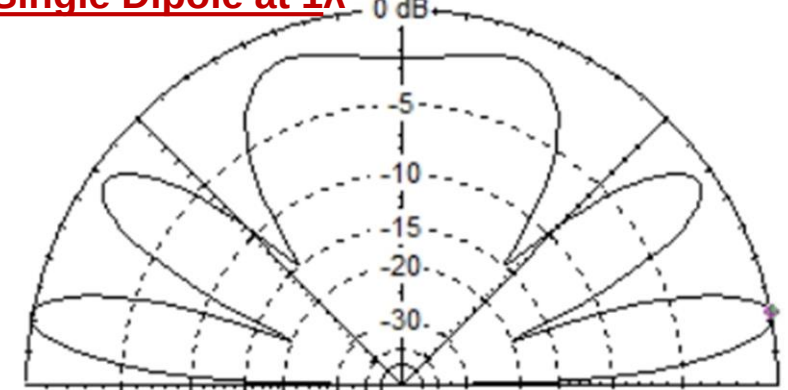


Stacked Dipoles – Great for High Bands

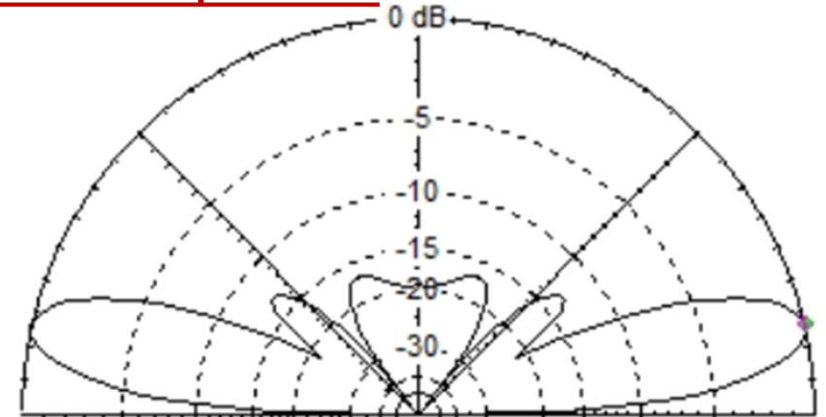


- Suppresses High Lobe at all installation heights
- Optimal spacing 0.6 to 0.75 λ
- Dipoles fed with $1/4 \lambda$ transformers (and $3/4 \lambda$)
- Reverse one dipole feed due to 180° shift.
- Tuning procedure

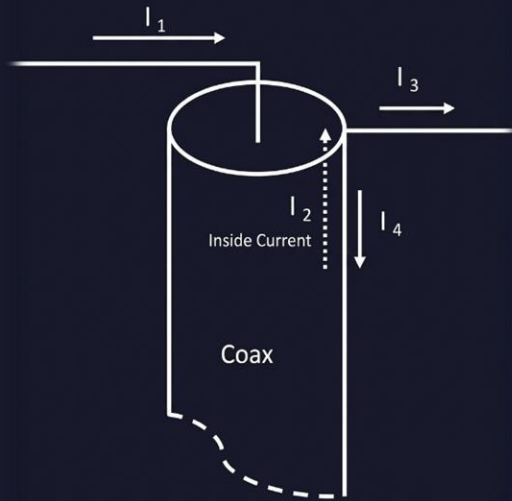
Single Dipole at 1λ



Stacked Dipoles at 1λ



Baluns and Common-Mode Chokes

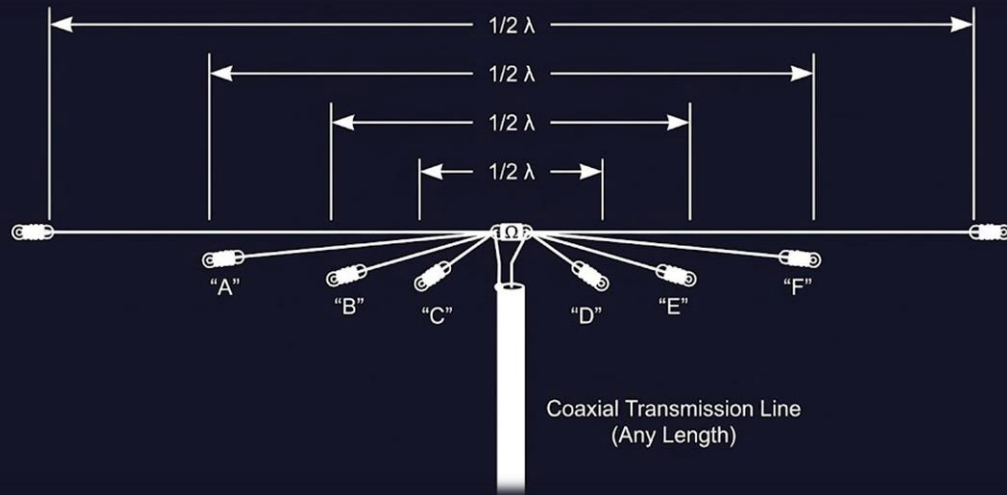


Coax has 3 conductors!

Types:

- Current Baluns (1:1, 4:1...)
 - Voltage Baluns (avoid)
 - Ferrite common-mode choke
-
- Balanced and Unbalanced
 - Feedline radiation, Noise Pickup, Distorted patterns, RF in the shack
 - Baluns and CM Chokes stop the RF on the outside of the coax

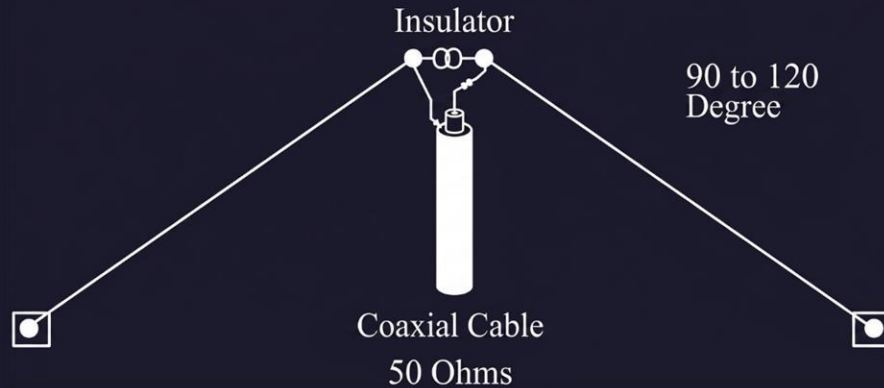
Fan Dipole – Multiple Resonant Wires



- Several resonant dipoles connected together
- No traps required, Efficient, Wide bandwidth
- Behaves like a Dipole
- Can be implemented as Inverted V
- Tuning, tuning, tuning...
- Excellent HF Multiband Solution (use 40m for 15m)



Inverted V – Bent Dipole

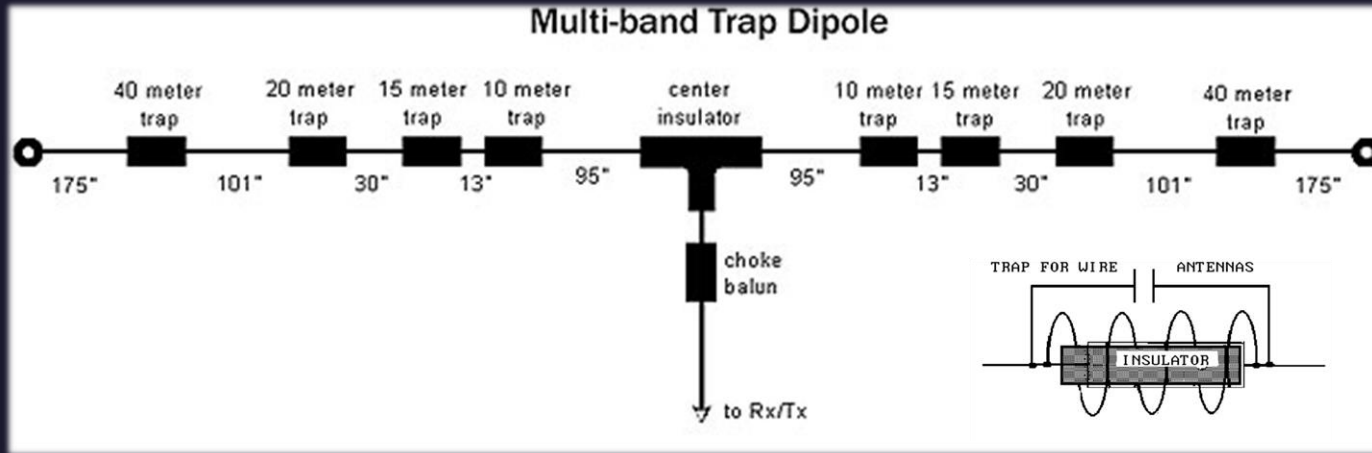
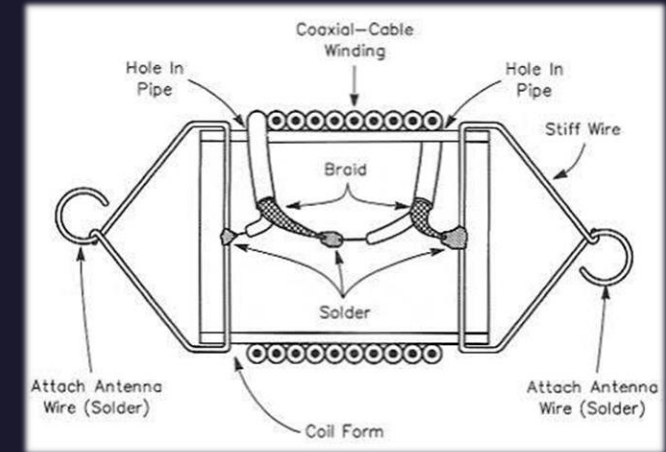


- Performance similar to dipole
- Single support structure, 90°-120° angle
- Feed-point impedance closer to 50Ω
- Radiation pattern becomes more omnidirectional
- Slightly lower gain than a flat dipole
- Excellent HF wire antenna: Easy to build, Efficient

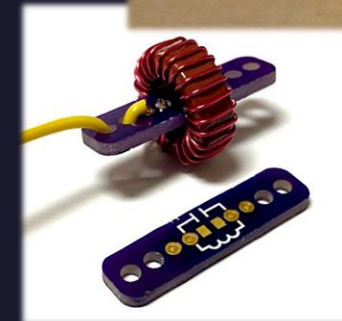


Multi-Band Inverted-V Fan

Trap Dipole – Electrically Isolate Sections

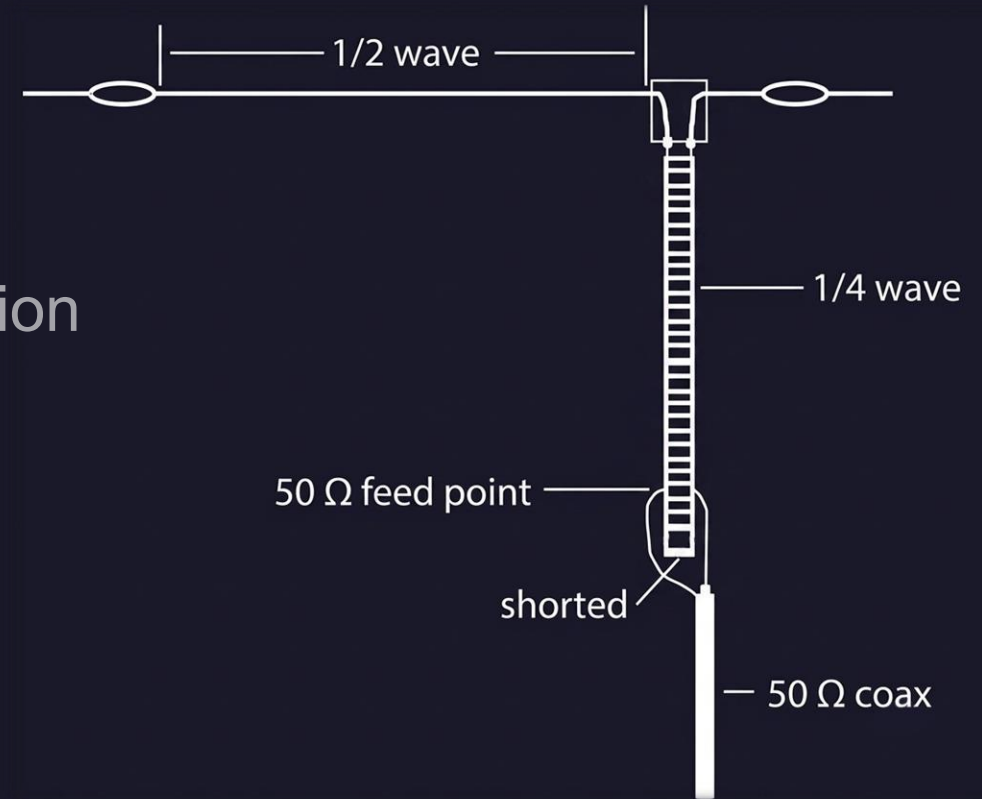


- Parallel Resonant Circuits as RF switches
- Narrower bandwidth, Trap losses, QRO issues
- Behaves like a Dipole
- Can be implemented as Inverted V
- Harder as DIY – need a way to tune the traps.
- HF Multiband Solution – not my favorite

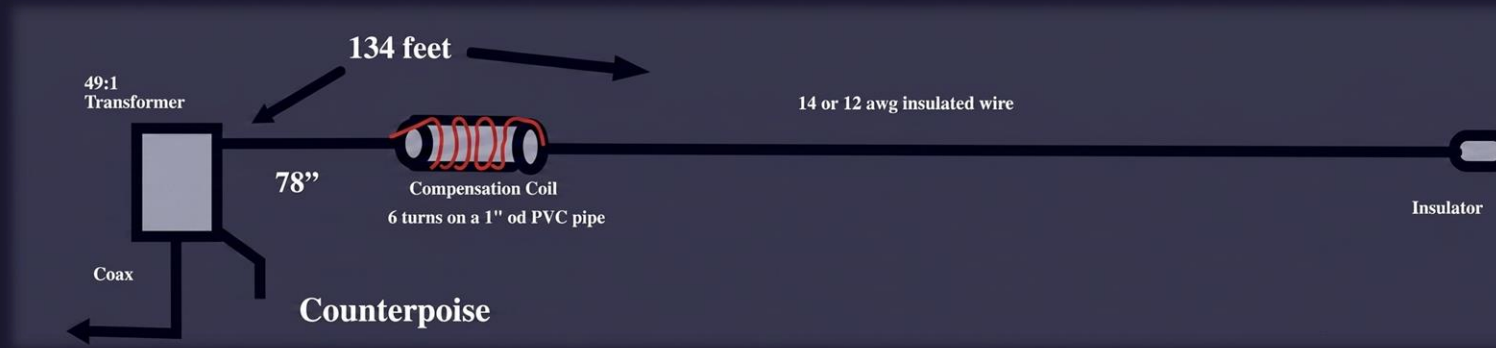


End-Fed Zepp Antenna

- End Fed single-band antenna
- Uses Ladder line as a $\frac{1}{4} \lambda$ matching section
- Low loss antenna
- Needs Balun or CM choke



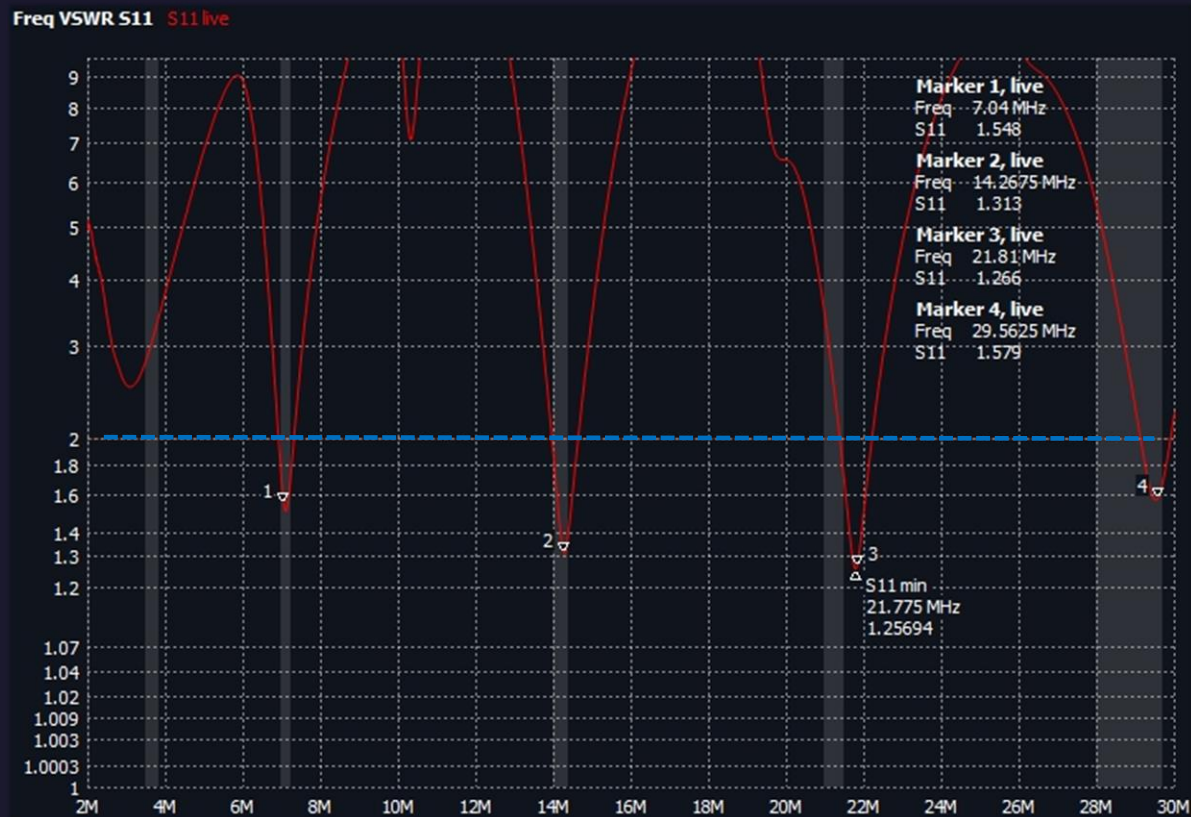
End-Fed Half Wave (EFHW)



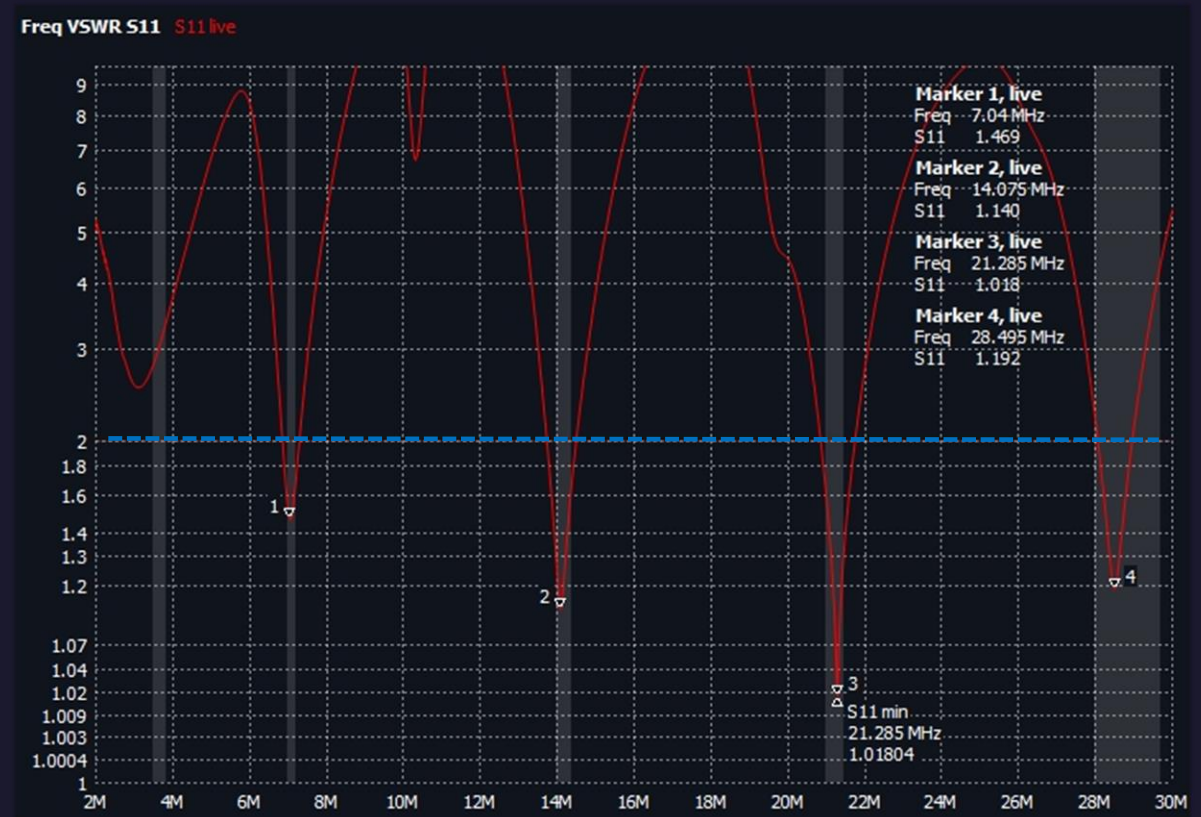
- Multi-Band Zepp - resonant on ALL $\frac{1}{2} \lambda$ harmonics
- ~2500 Ω feed-point, needs 49:1 wideband transformer
- Needs Counterpoise! Needs good CM Choke!
- Complex Radiation pattern on higher harmonics
- Can be implemented as Inverted V, Inverted L, etc.
- Tuning: Needs Loading Coil to optimize multi band resonance
- Very popular Beginner HF Multiband Solution – not QRO friendly

EFHW Compensation Coil Effect

Without Coil

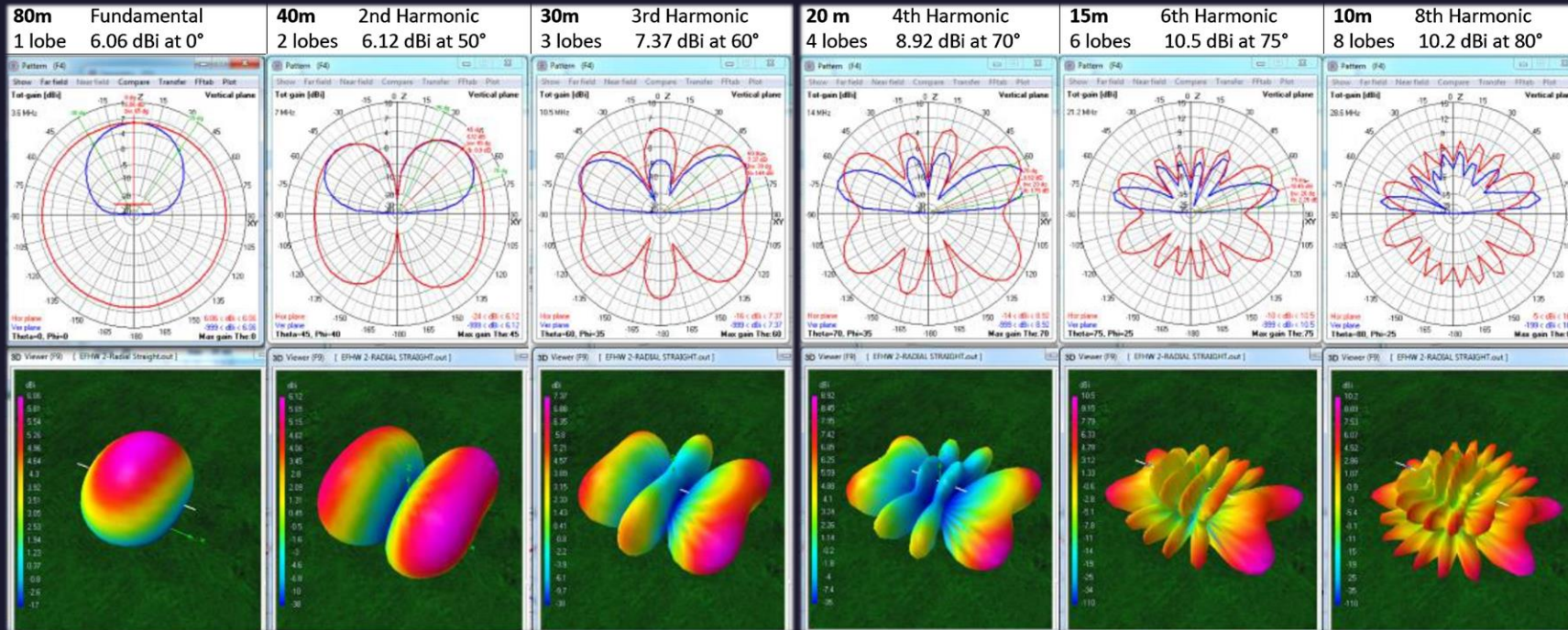
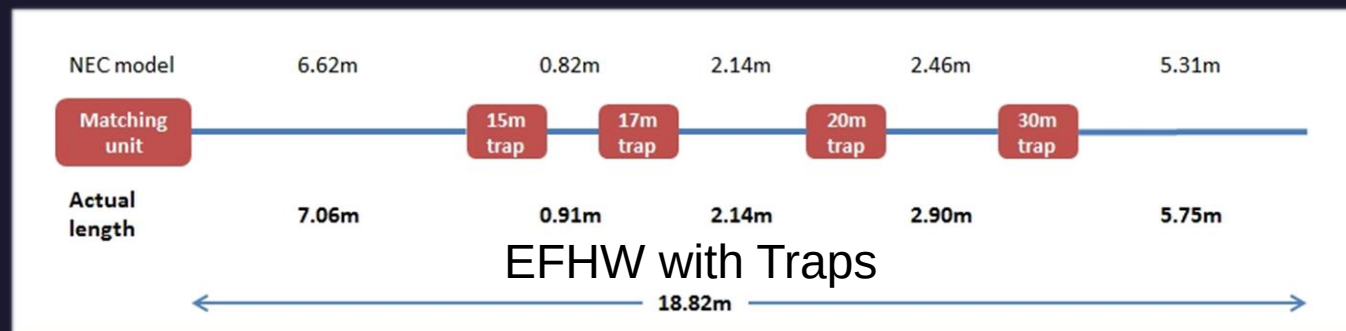


With 1.5uH Coil

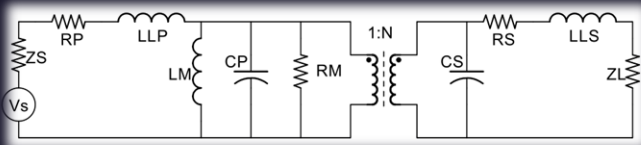
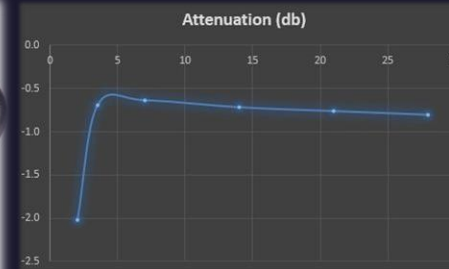
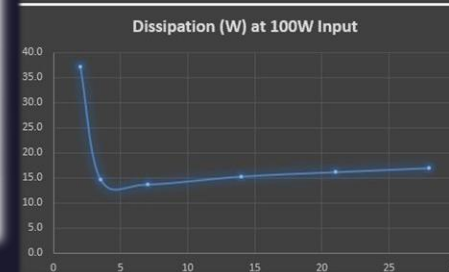
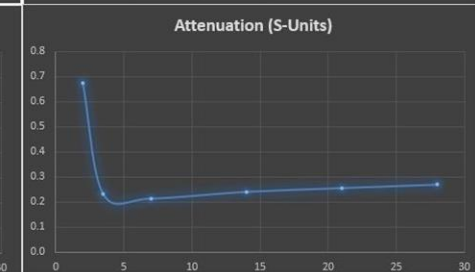


EFHW Radiation Patterns

At 60 feet height



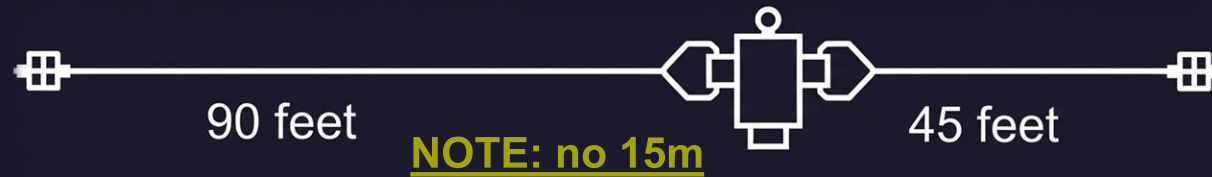
EFHW Unun (49:1 Transformer)



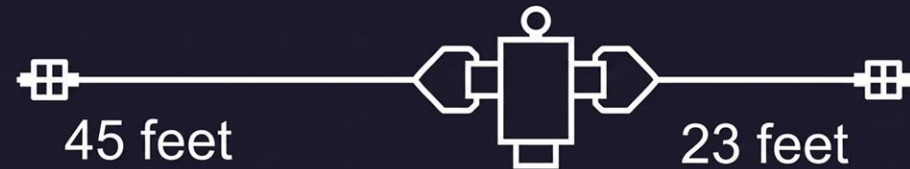
- Limiting system component
- Many designs in the web – most of them unfit
- Better to buy a reputable device
- **DO NOT OMIT GOOD BROADBAND CM CHOKE!**



Off-Center-Fed Dipole (OCFD)



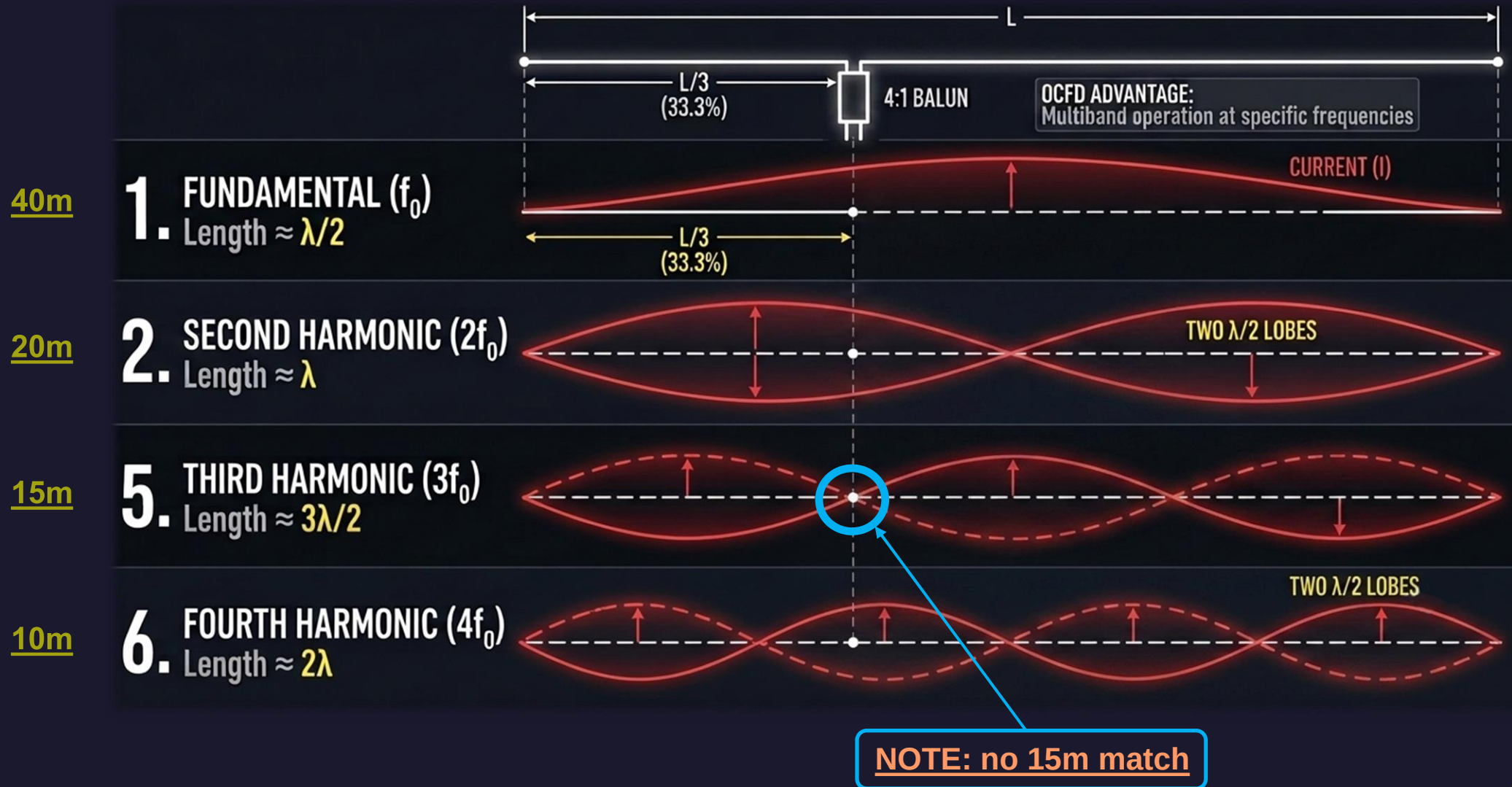
80-6M 7 BANDS 80, 40, 20, 17, 12, 10, and 6 meters



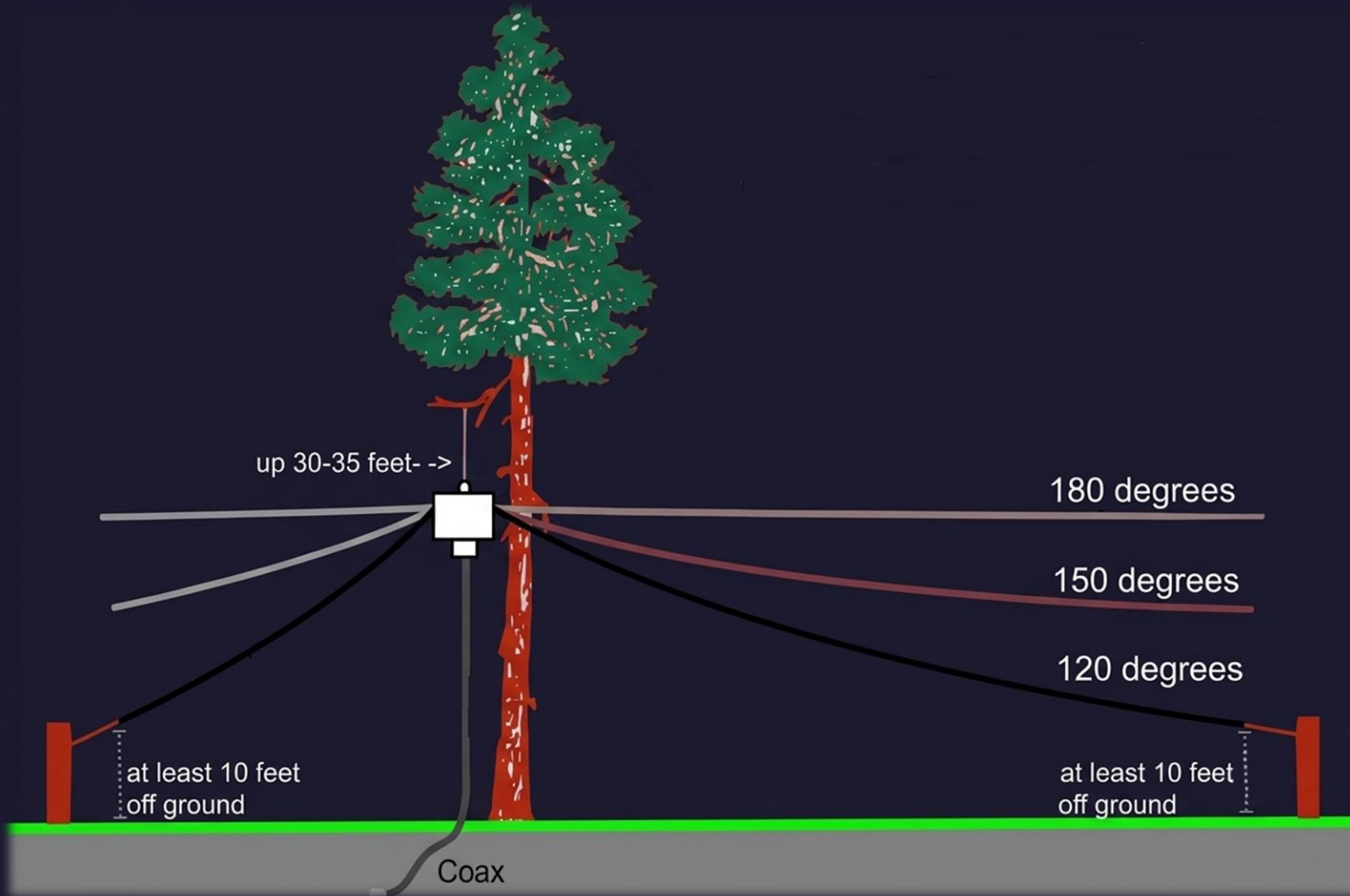
40-6M 4 BANDS 40, 20, 10, and 6 meters

- Covers multiple HF bands with one antenna
- Fed 33% (28-36%) of length from one end.
- ~200Ω (300Ω) feed, needs 4:1 wideband transformer
- Often used without a tuner on its primary bands
- Complex Radiation pattern on higher harmonics
- Very popular HF Multiband Solution

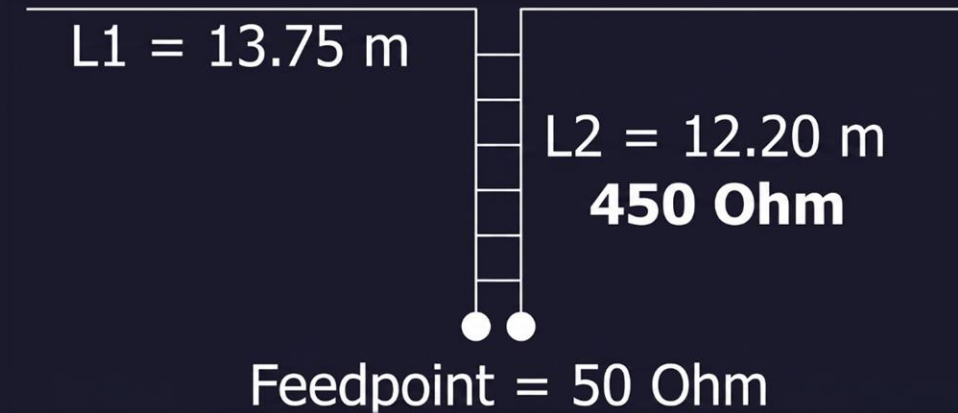
Off-Center-Fed Dipole Resonance



Off-Center-Fed Dipole Installation



ZS6BKW Dipole



- Modified G5RV antenna
- $\frac{1}{2} \lambda$ dipole with integral 450 (or 300) ohm ladder line
- Ladder line acts as a matching system and/or a radiator
- Not resonant on all bands, but presents low VSWR (not the same)
- Low VSWR on 40, 20, 17, 12, 10m – no 80 and 15m without tuner
- Needs 1:1 Balun or CM choke – QRO Friendly

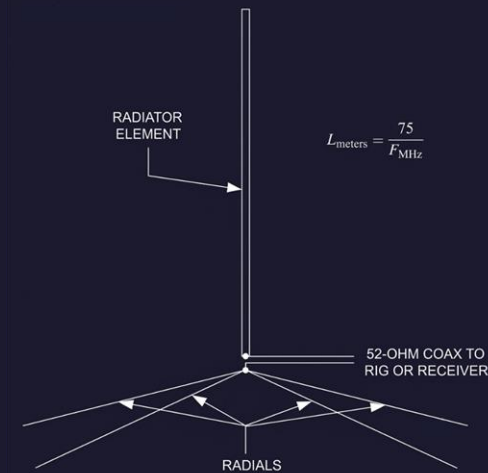
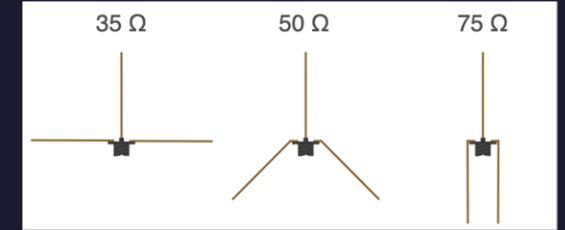
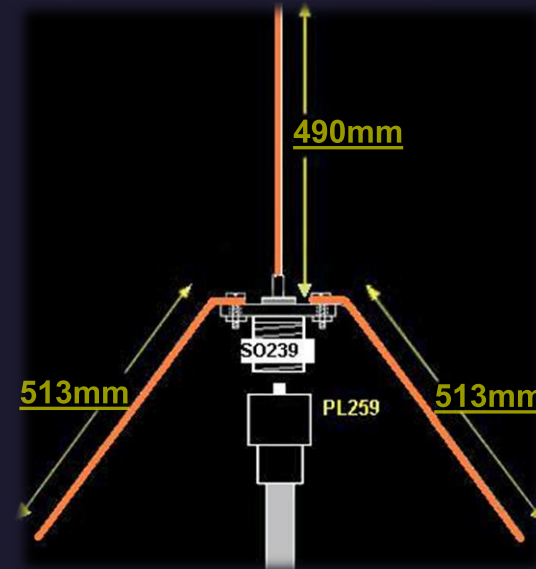
Vertical Antennas - Why Use a Vertical?

- Low takeoff angle, but lower gain
- Omnidirectional
- Implementations: $\frac{1}{4} \lambda$, $\frac{1}{2} \lambda$, $\frac{5}{8} \lambda$
- **Best used on low bands**
- Higher receive noise (QRN & QRM)
- Ground losses
- Often Misunderstood



Classic Ground Plane Vertical

- Not a space saving antenna on HF
- Vertical Dipole – Gnd is the other half
- ~32Ω feed-point
- Needs 32+ radials for HF DX performance
- Elevated (tuned) Radials
- Can be multiband



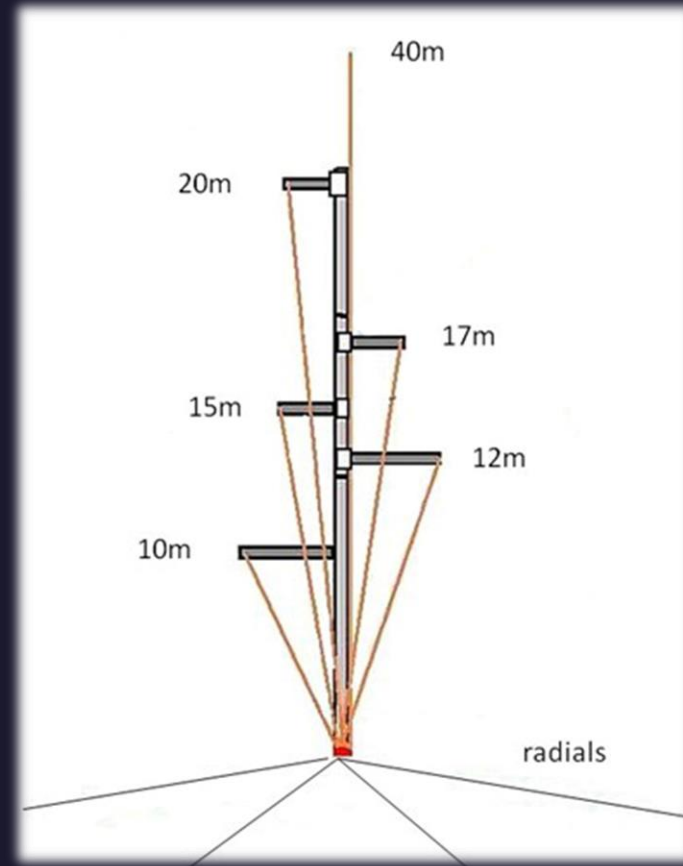
2m DIY Ground Plane



23cm DIY Ground Plane

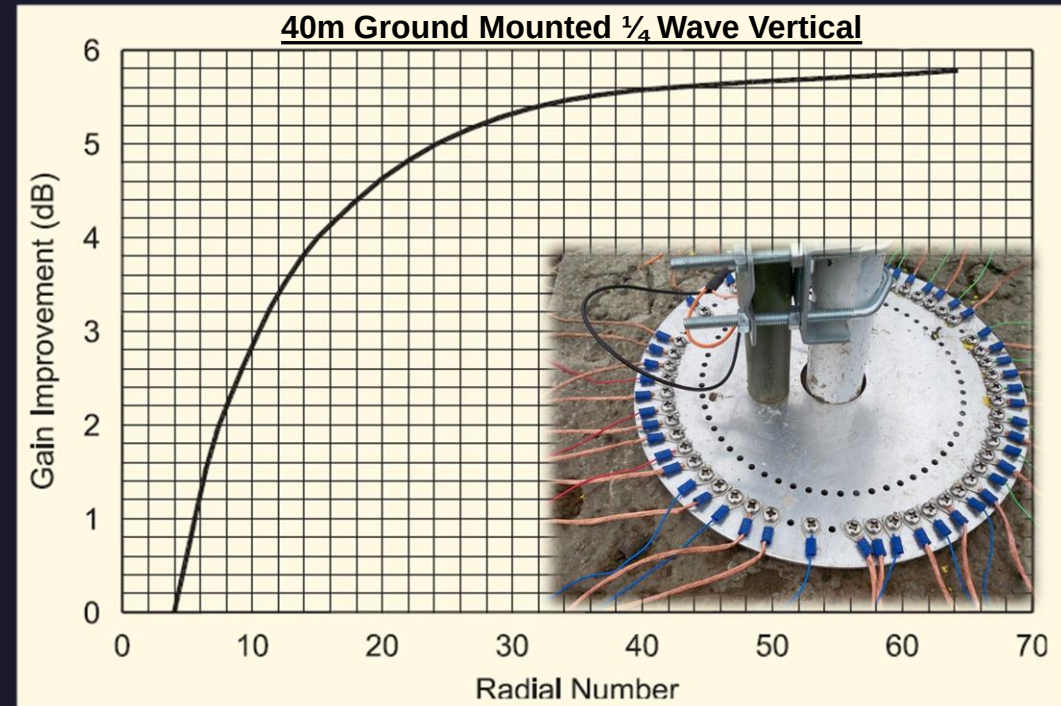
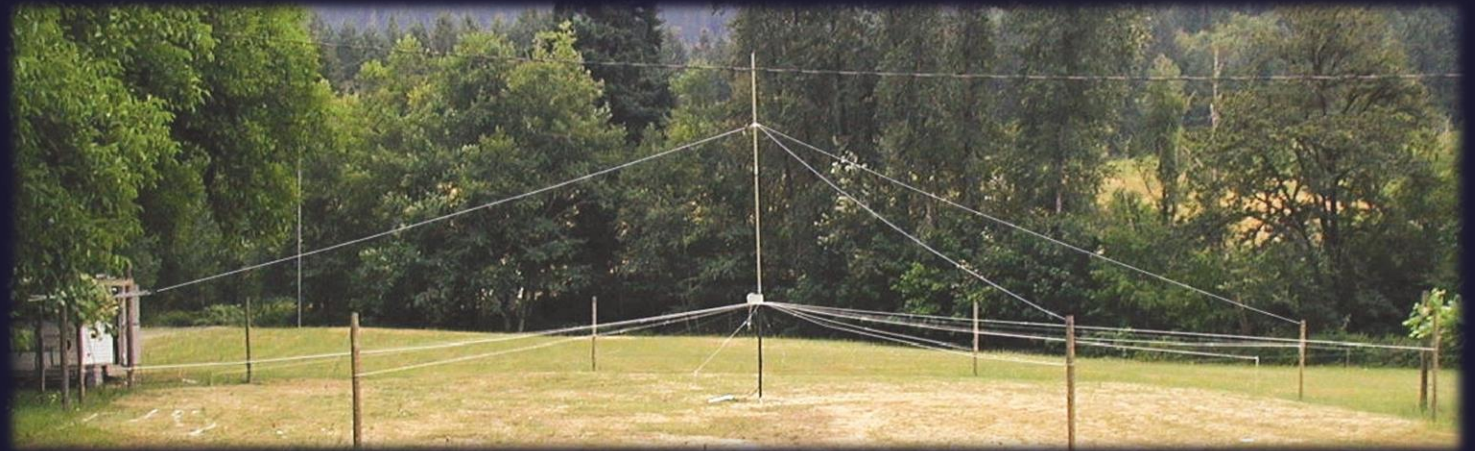
Fan Vertical (DX Commander)

- The Vertical Fan Dipole variant
- Multiple quarter-wave elements
- Shared radial system
- Developed by Callum McCormick
- DIY versions easily made
- Tuning
- Good DX Performer



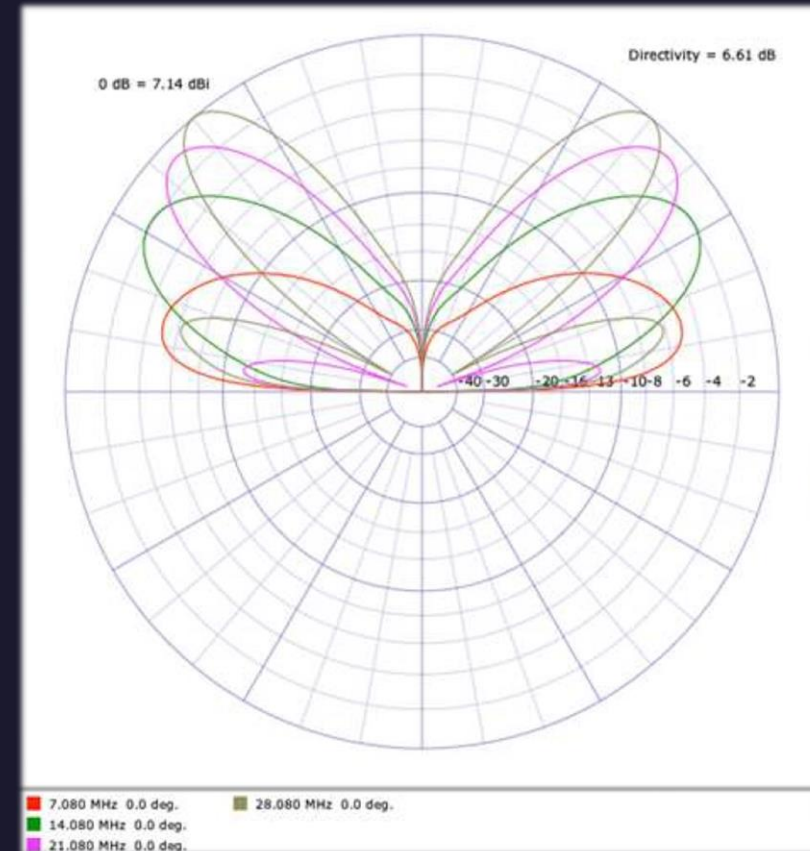
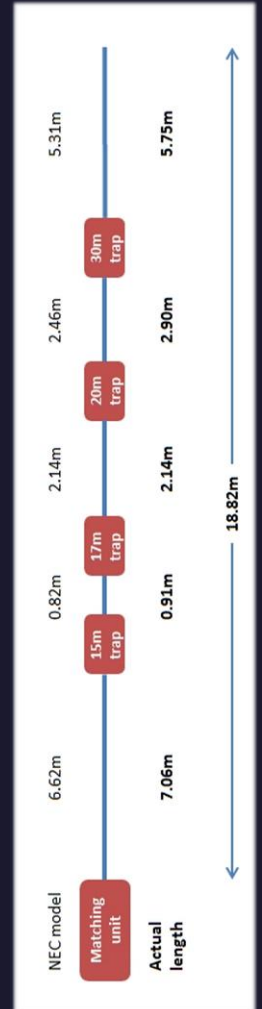
About Radials...

- **Vertical's most important part!**
- The radial field is half the antenna
- GND Radials: More is better (32+)
- Elevated Radials:
 - Tuned $\frac{1}{4} \lambda$ Radials for each band
 - 1 elevated = 8 ground radials
 - 1 ft. or more above ground
 - Much lower ground loss
 - Roof Installations



End Fed (Half Wave) Verticals

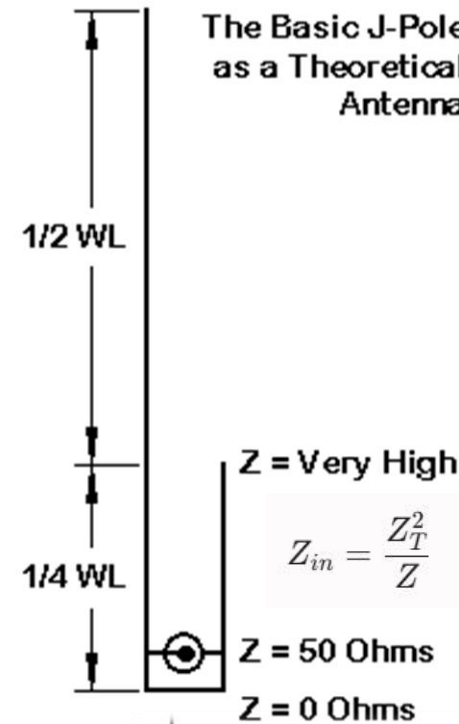
- Single-Band vertical EFHW Dipole
- Multi-Band using “Traps” or linear loading
- Cannot be made into a DIY Fan!
- No radials, only small counterpoise(s)
- Commercial Examples:
 - Cushcraft R8
 - Hustler 6BTV
 - Hy-Gain AV series



J-Pole Verticals

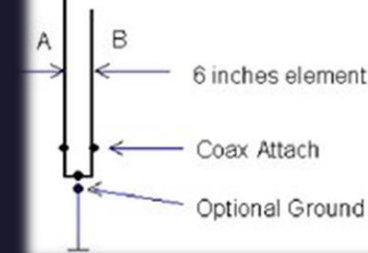
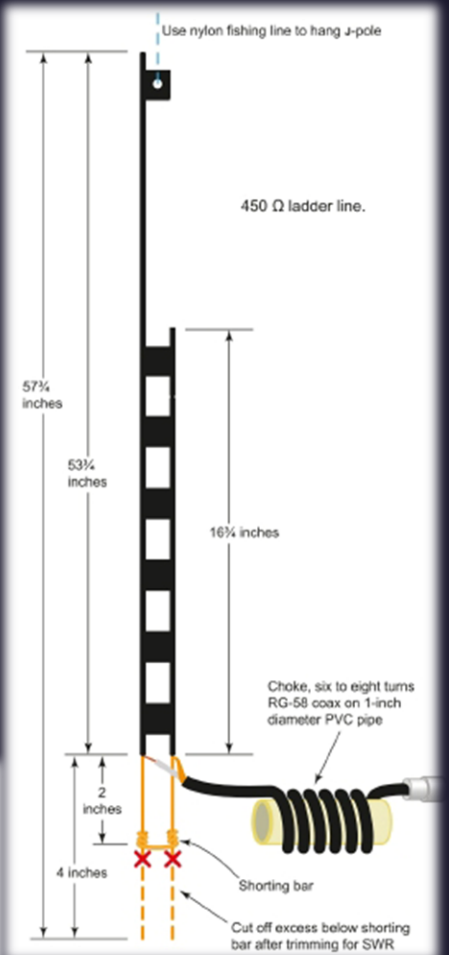
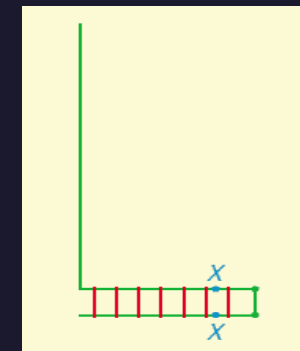
- End Fed Zepp Variant
- Single-Band vertical
- No radials or counterpoise(s)
- Matching section can be horizontal
- Needs CM choke!
- Common on VHF+, but also used on HF
- Excellent performer when well constructed and choked!

The Basic J-Pole
as a Theoretical
Antenna



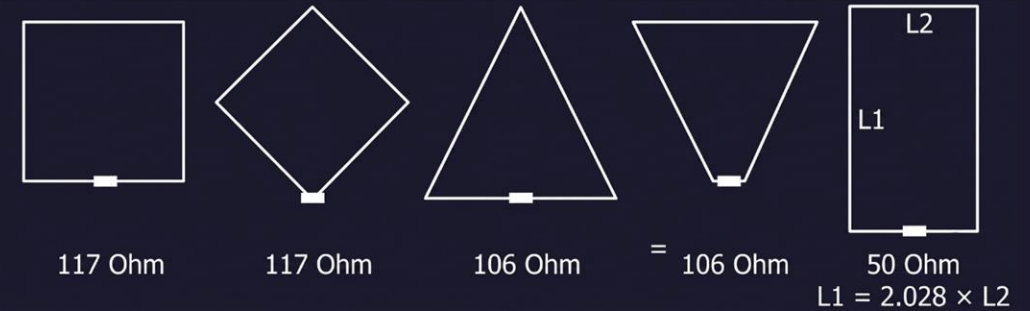
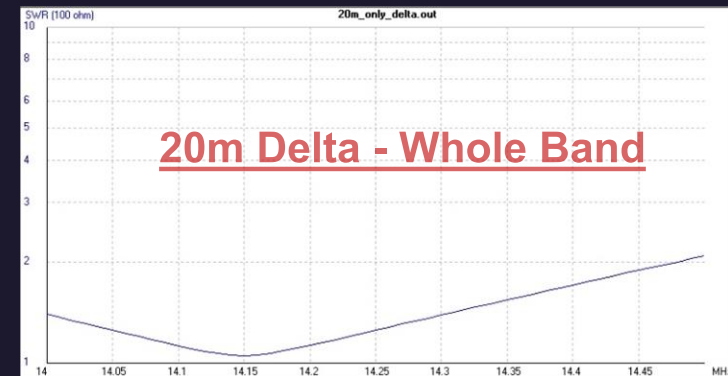
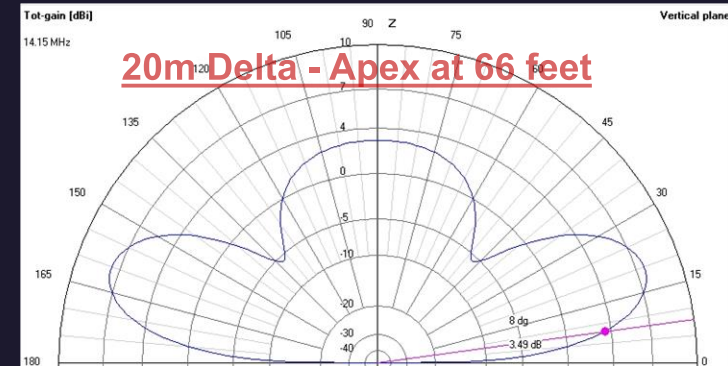
PVC 6" spreaders omitted for
Antenna wire #14

	20	40
A Length	48.75 ft.	97.5 ft.
B Length	16.45 ft.	32.9 ft.
Attach Length	8 inches	16



Full Wave Vertical Loop Antennas

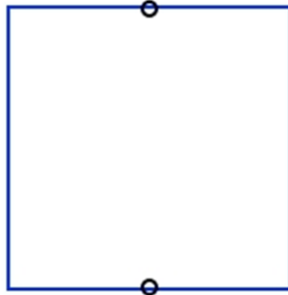
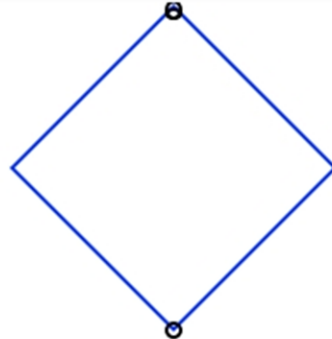
- Higher gain than Dipole (1.4dBd)
- Very quiet (1-2 S-units less QRN)
- Multi-Band possibilities
- ~110 ohm feed-point (2:1 Balun)
- Lower take-off angle than Dipole
- Selectable polarization via feed-point



Loop Antenna Variations

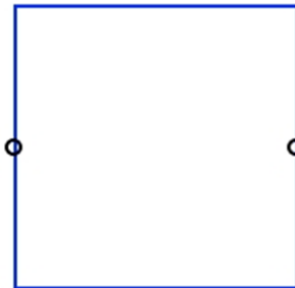
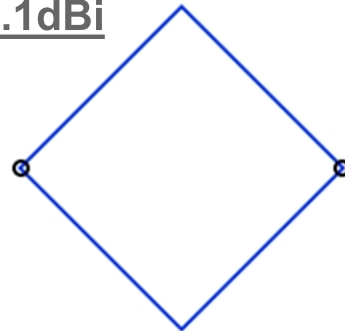
Dual Support

Single Support



Feedpoints for Horizontal Polarization

Gain: 3.1dBi

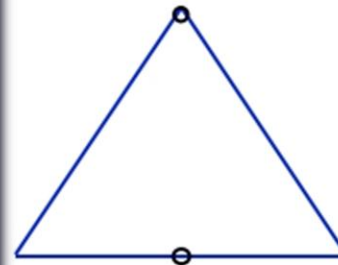
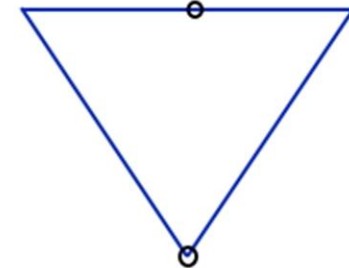


Feedpoints for Vertical Polarization

Square Loops

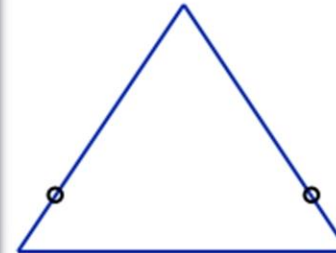
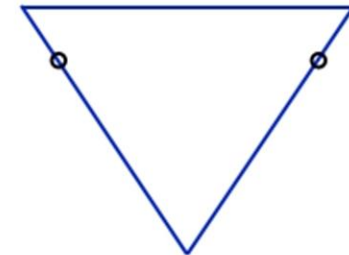
Single Support

Dual Support



Feedpoints for Horizontal Polarization

Gain: 2.9dBi

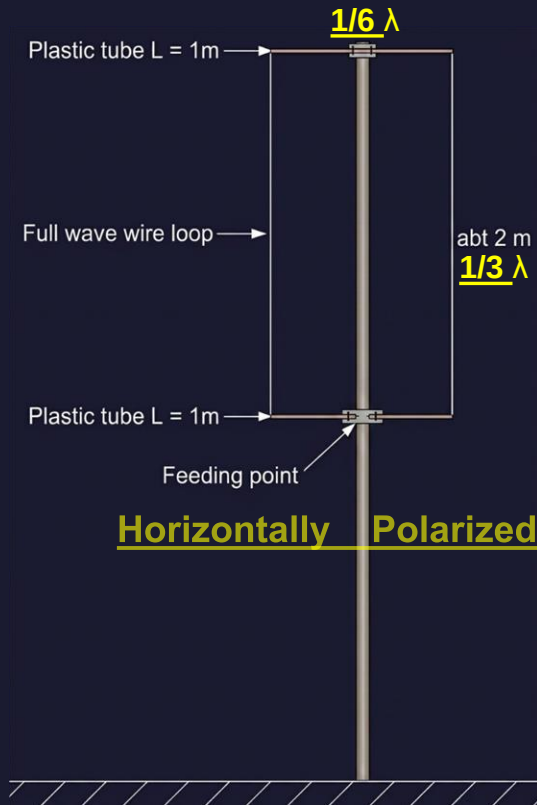
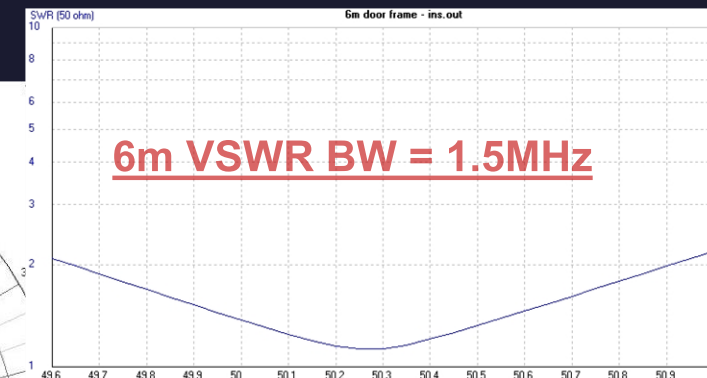


Feedpoints for Vertical Polarization

Delta Loops

Door-Frame Loop Antennas

- Elongated Loop Antenna
- Shares Loop Antenna properties
- 50Ω feed (needs CM Choke)
- Broadband
- Lower take-off angle than Dipole
- AI2F Carolina Cross
- Great as 6m or 2m attic antenna



Antennas for HOA and Restricted Properties

- Many amateurs face restrictions on:

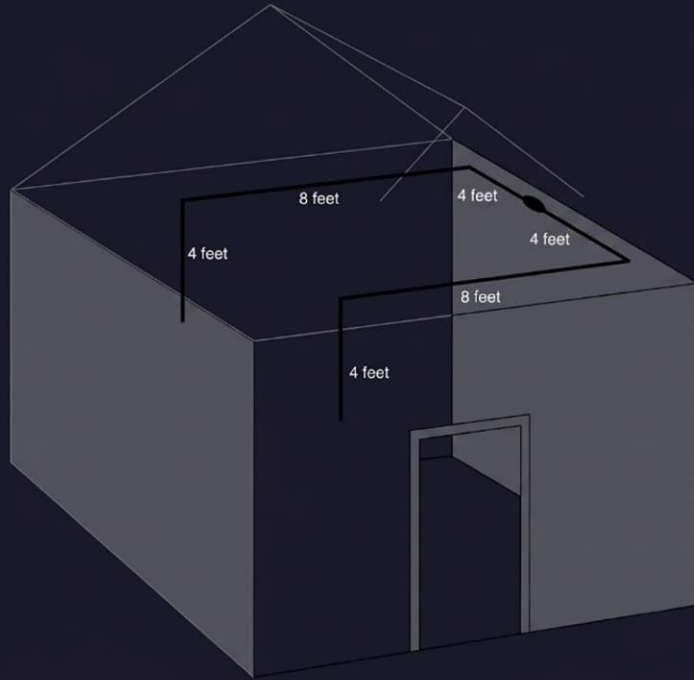
- Towers
- Visible antennas
- Roof-mounted structures
- Permanent outdoor installations
- Property modifications

- The good news:

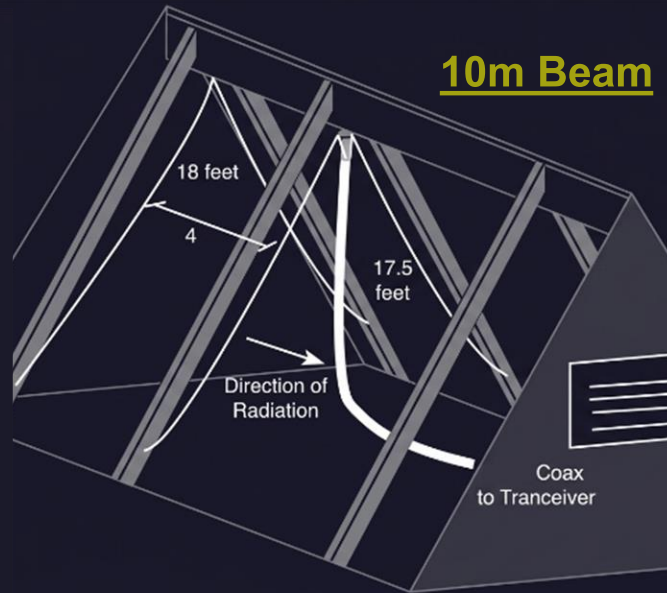
- Almost every property can support some form of HF antenna.



Attic and Indoor Ideas



Multi-Band Ceiling/Attic Dipole



20-10m Square Halo (Cobbweb)



20-15-10m Fan Dipole



Apartment / Condo Dweller Ideas



HOA Decision Matrix

HOA Situation	Best Strategic Wire Match	Primary Disadvantage	DX Potential
Complete Outdoor Wire Ban	Attic Fan Dipole, Random Wire with Auto Tuner	Detuning, high local noise pickup	Low to Moderate
Strict View Covenants / Trees Allowed	Stealth EFHW or Fan Dipole	EFHW CM feedline current risks	Excellent
Front Lawn Restriction Only	Decorative Flagpole Vertical	Requires heavy radial network	Good (DX-focused)
Fully Fenced Perimeter Yard	Fence Perimeter Loop	Ground absorption losses (Low height)	NVIS Regional Match



Coaxial Feedlines

Coaxial Cable Type	Loss @ 3.5 MHz (dB/100ft)	Loss @ 14 MHz (dB/100ft)	Loss @ 30 MHz (dB/100ft)	Best Use Case
RG-58	0.8 dB	1.8 dB	2.5 dB	Avoid - Portable / QRP / Short Runs
RG-8X	0.5 dB	1.0 dB	1.8 dB	Suburban Low Bands Run
RG-213	0.4 dB	0.7 dB	1.1 dB	High Power / Heavy Duty Direct Burial
LMR-400 KMR-400	0.2 dB	0.5 dB	0.7 dB	Long VHF/UHF runs, Good HF DX Setup



Antenna Construction Materials

Fiberglass

Fiberglass Rebar (GFRP)
3/8" , 1/2" and 3/4" (10 & 20ft)
Telescoping Fiberglass Poles
20-40 feet



PVC

Innexpensive
Easy to work with
Waterproof
Readily available

Rope

UV-Resistant Dacron Rope
Preferred for antenna
support
Low stretch
Excellent weather resistance
Avoid:
Nylon rope, Polypropylene
rope, Paracord



Wire

Stranded Copper Wire
Copper Flexweave
Insulated or Bare
Copper-Clad Steel (Copperweld)
12, 14, 16, 18 AWG



Tools

NanoVNA-H



9kHz -1.5GHz, \$45

NanoVNA-H4



9kHz -1.5GHz, \$90

NanoVNA-F V2



50kHz -3GHz, \$125

Rig Expert

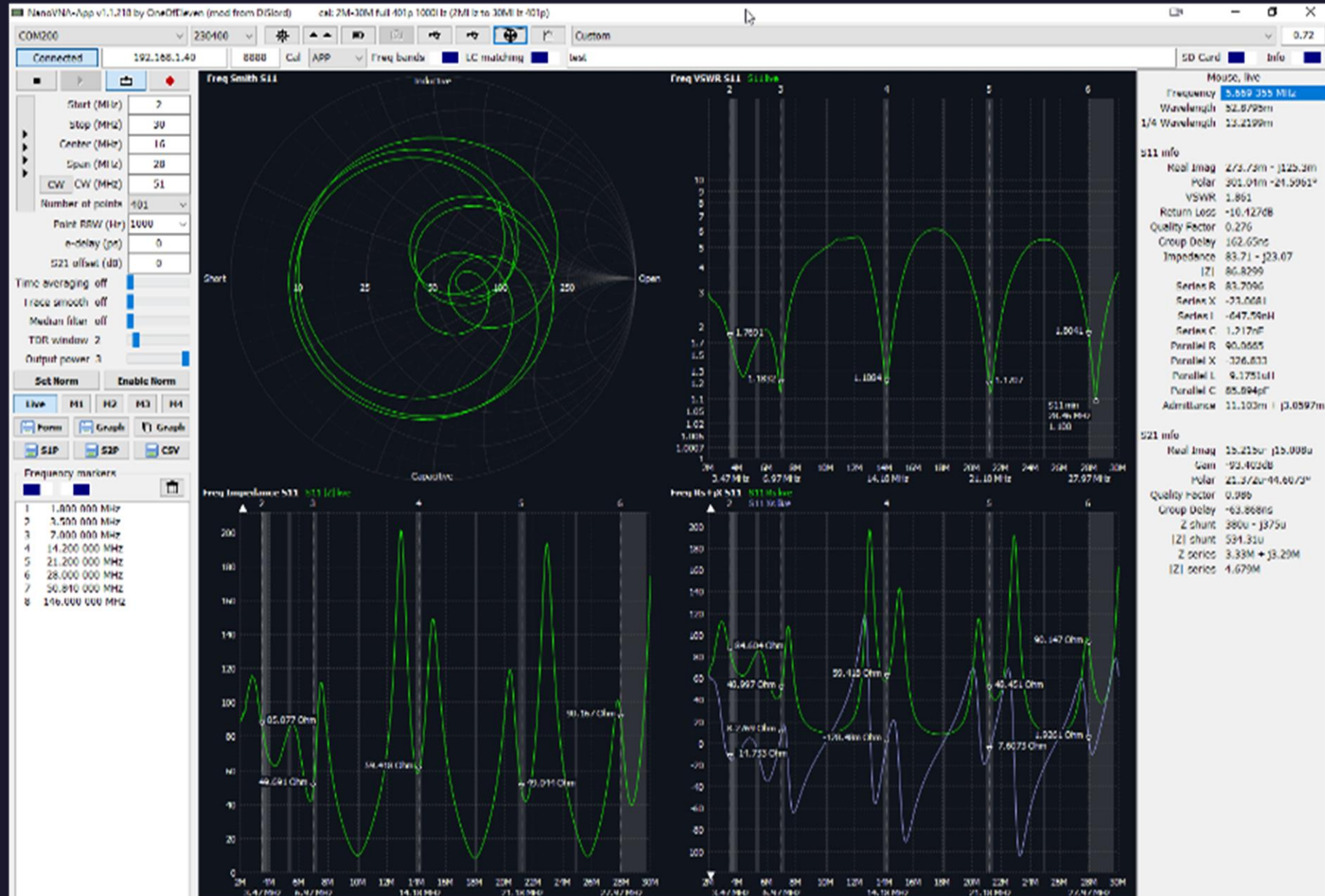


\$300+

VSWR Meter



NanoVNA-App (or NanoVNA-Saver)



Finally

- There is no universally “best” HF antenna
- There is only the best antenna for:
 - the space you have
 - the bands you operate
 - the propagation you want
 - the direction in which you want your signal to go



Thank you Questions?

Christopher S. Krstanovic, Ph.D

ai2f@NovaLab.org

www.CARS-NC.org

