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

*** *PDF available for download on CARS-NC.org*

AI2F

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

Ideal Antenna?

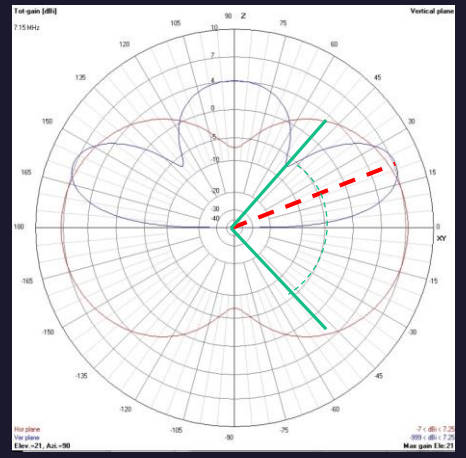
Antenna Myths:

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

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.

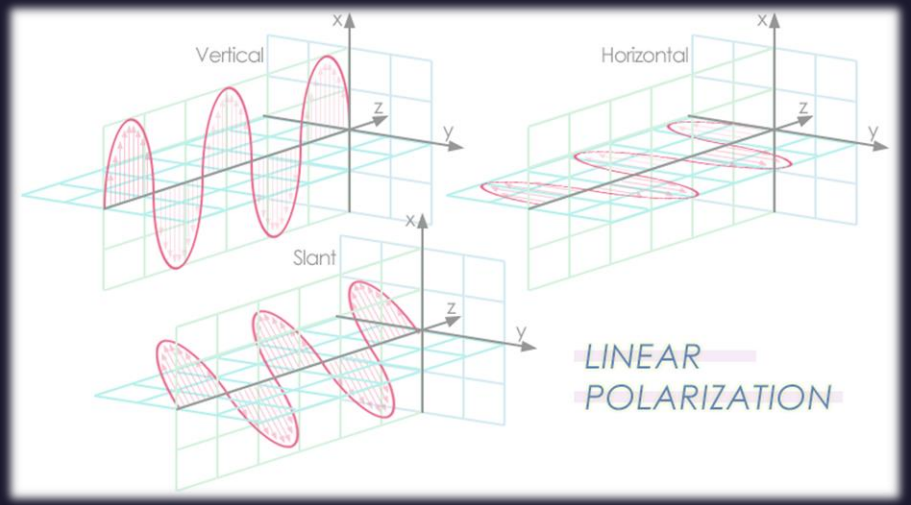
Key Antenna Parameters

- 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

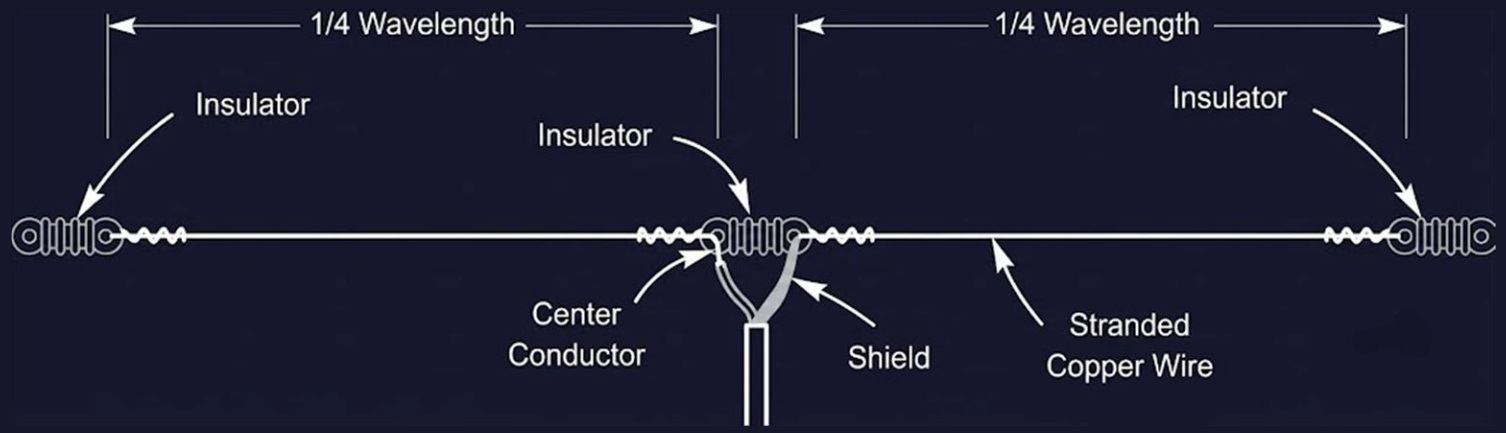
Wire Beams

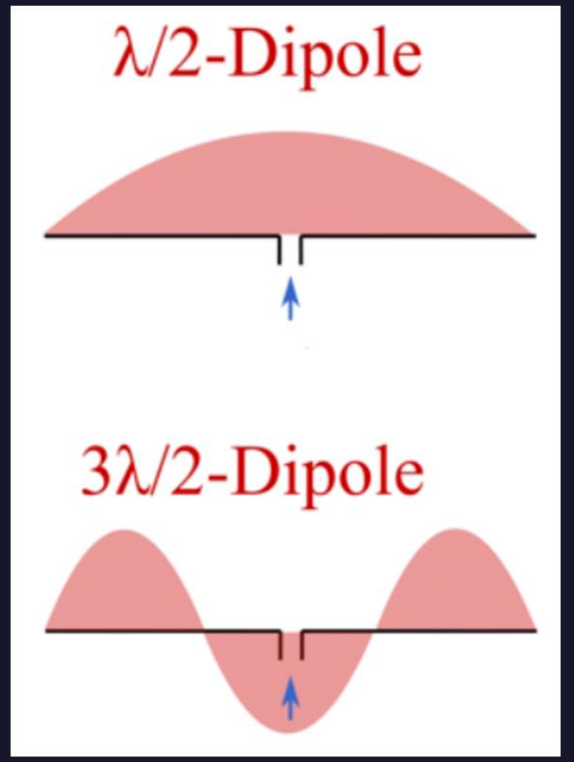
Excellent Performers
Nice F/B
Need Rotators and Support
DIY Options readily Available
Can be made for ~$150

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



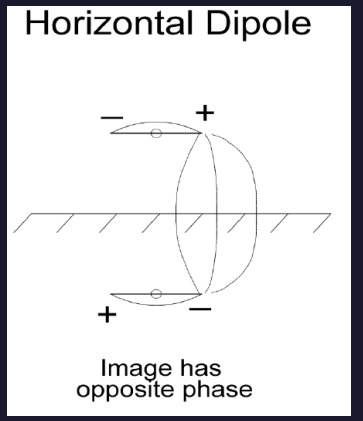


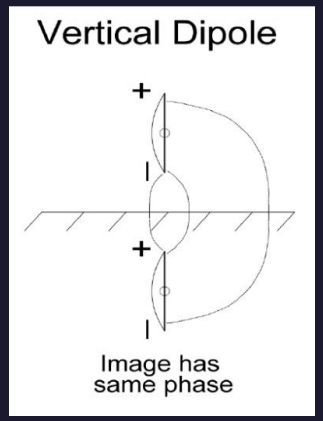
- Resonant on one band (also on 3rd, 5th… overtones)
- Feed-point impedance ~72Ω in free space
- Predictable performance
- Simple and inexpensive
- Truly Foundational - Many variations
- Excellent first HF antenna: Easy to build, Efficient

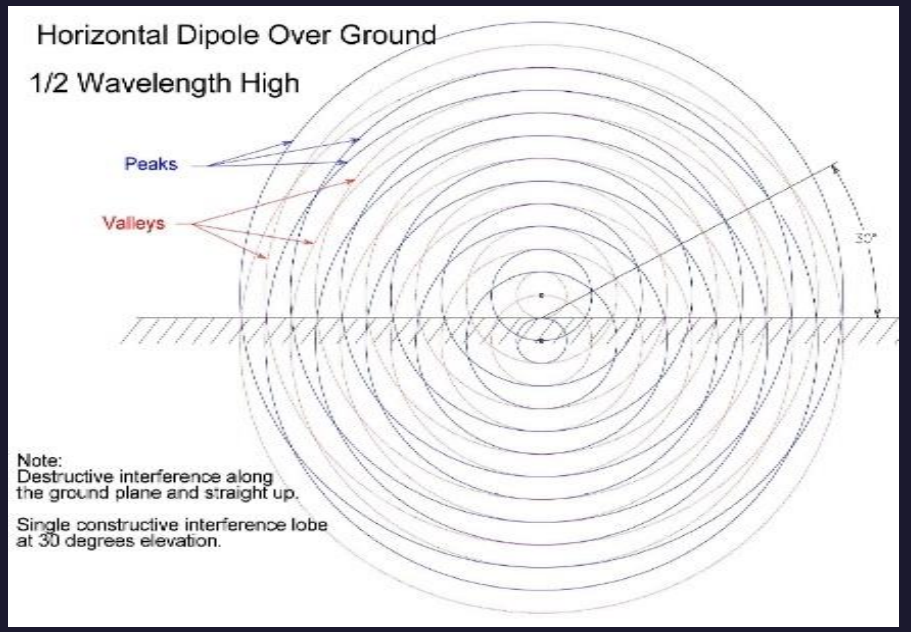
Antenna Height

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 ¼ λ radiate mostly straight up
- At ½ λ+ antennas develop excellent low-angle radiation
- Above 1 λ multiple radiation lobes and nulls appear
- Increasing antenna height improves DX performance







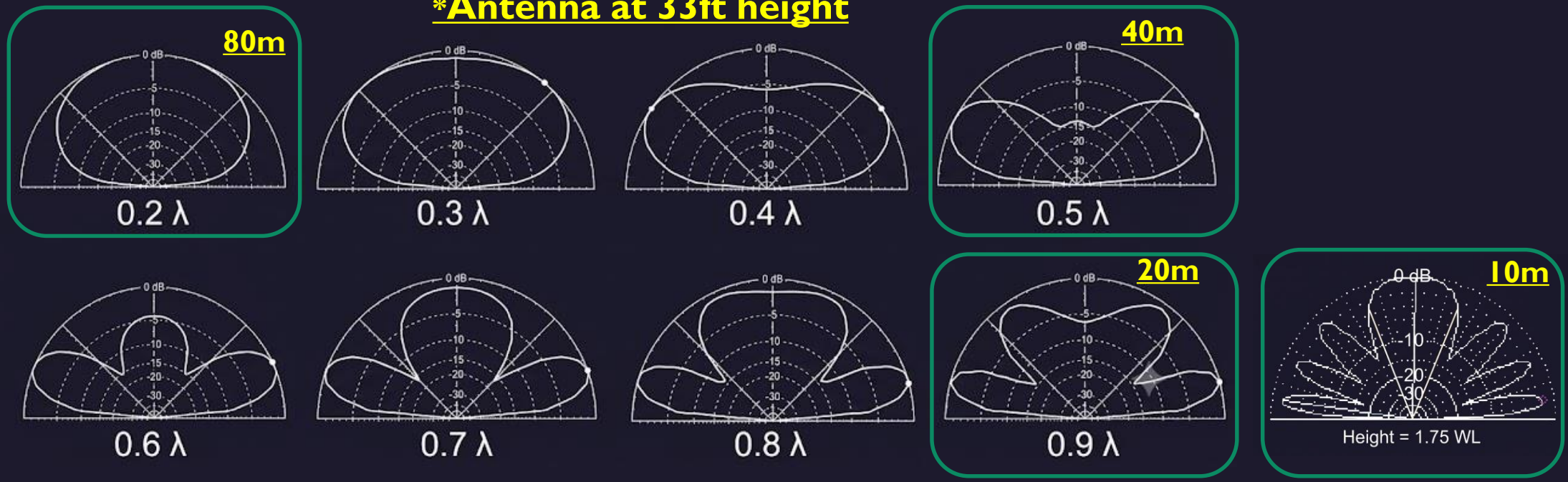
Sidebar: Where does DX Come From?

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

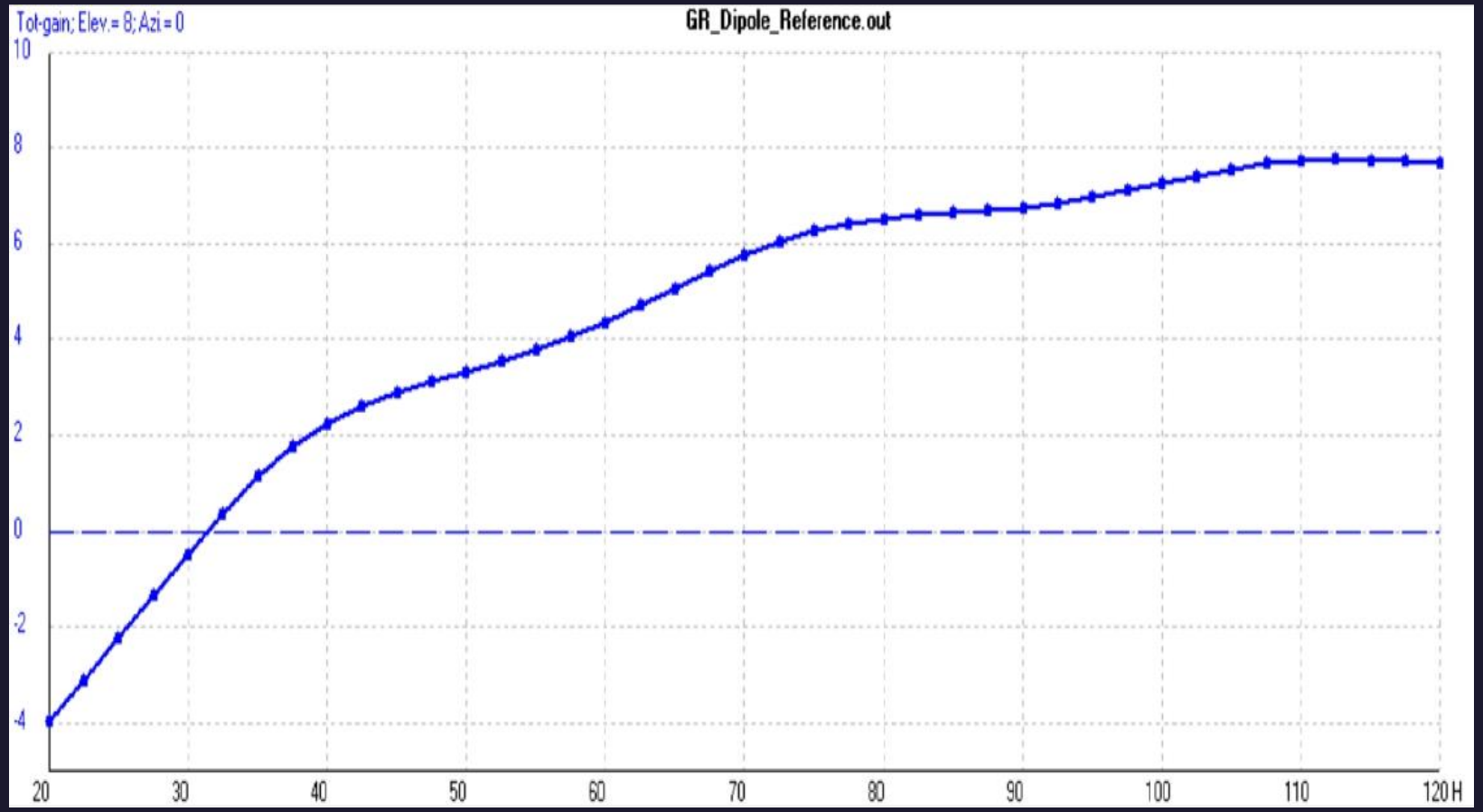
***Antenna at 33ft height**



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

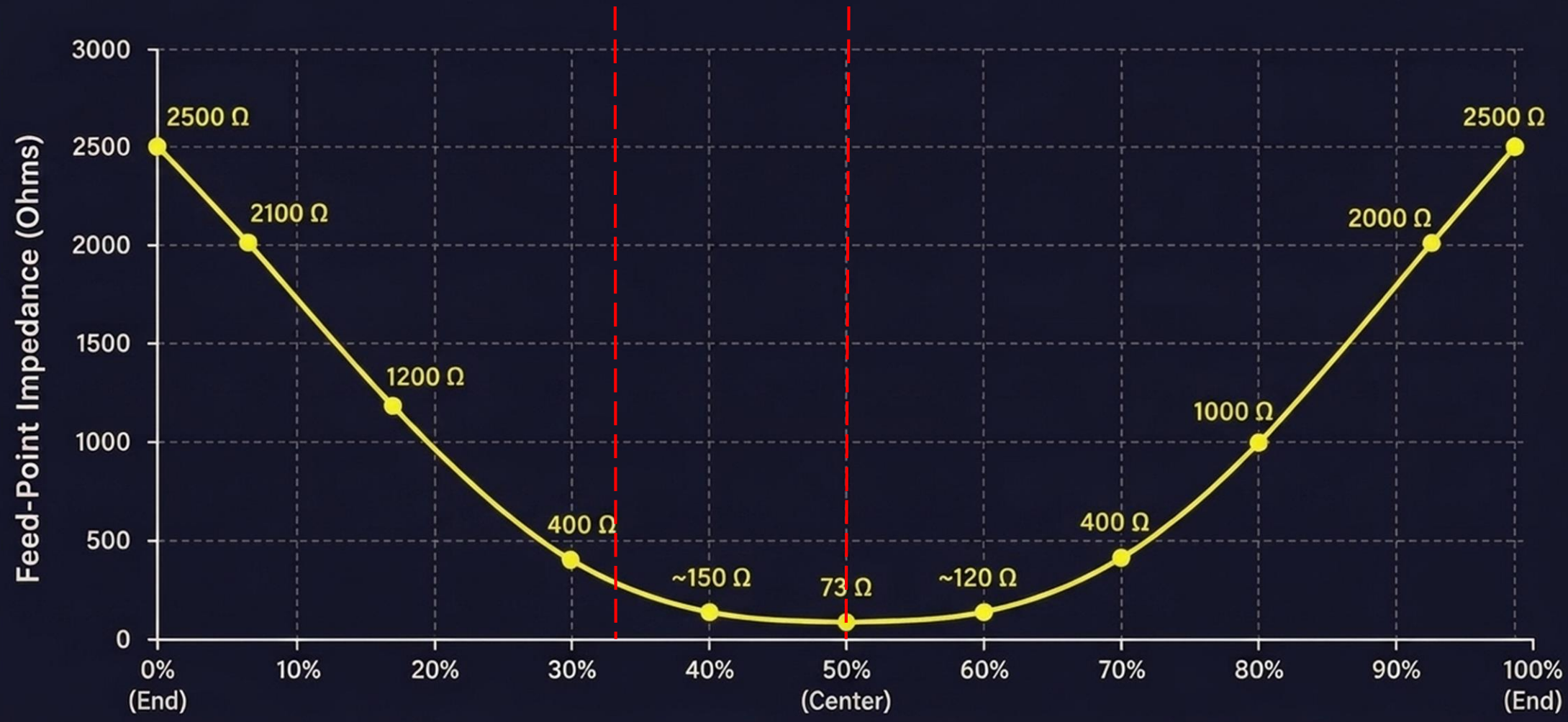
Horizontal 20m Dipole Gain at 8 deg elevation



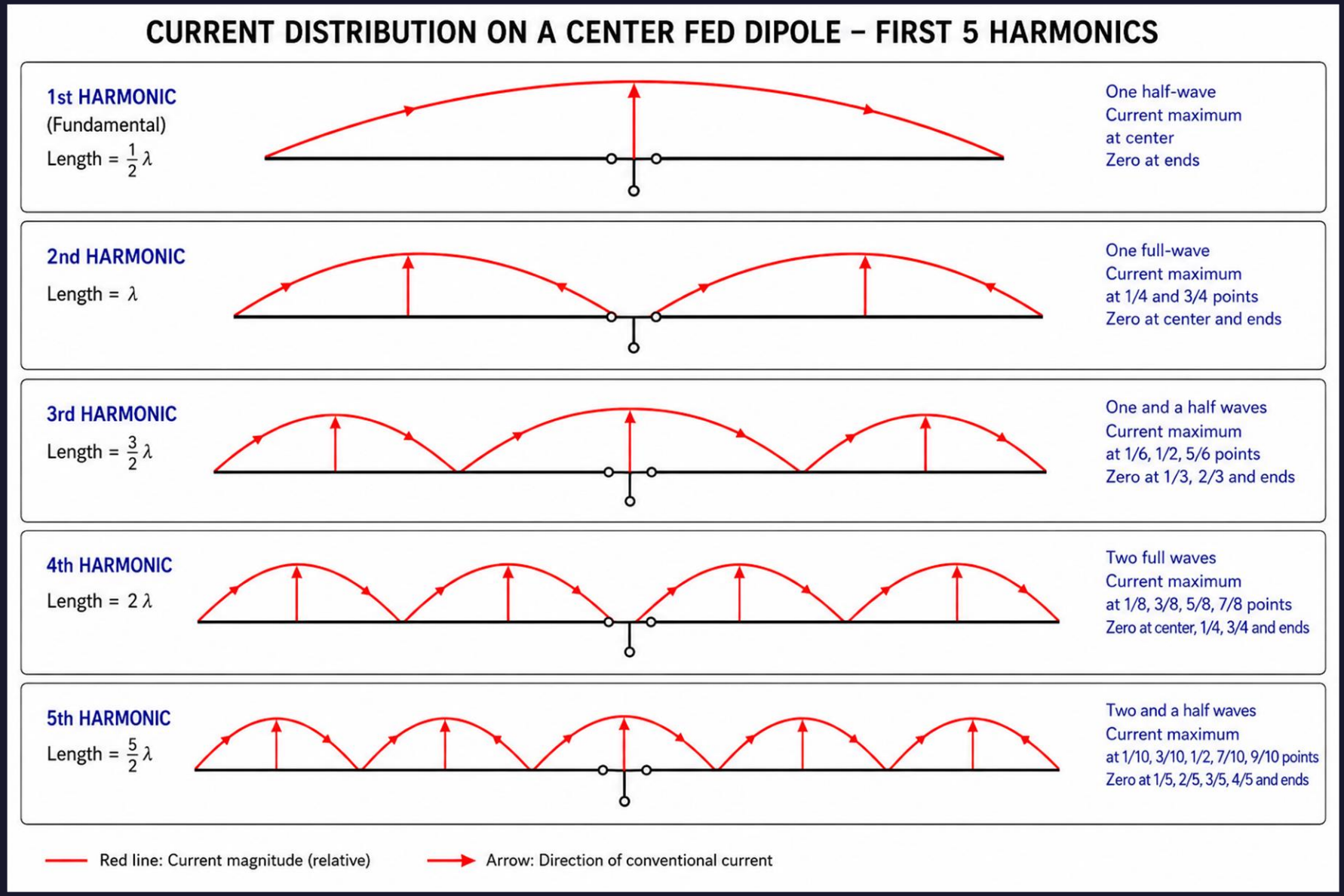
Height in feet

Dipole Feed-Point Impedance vs. Full Dipole Location

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



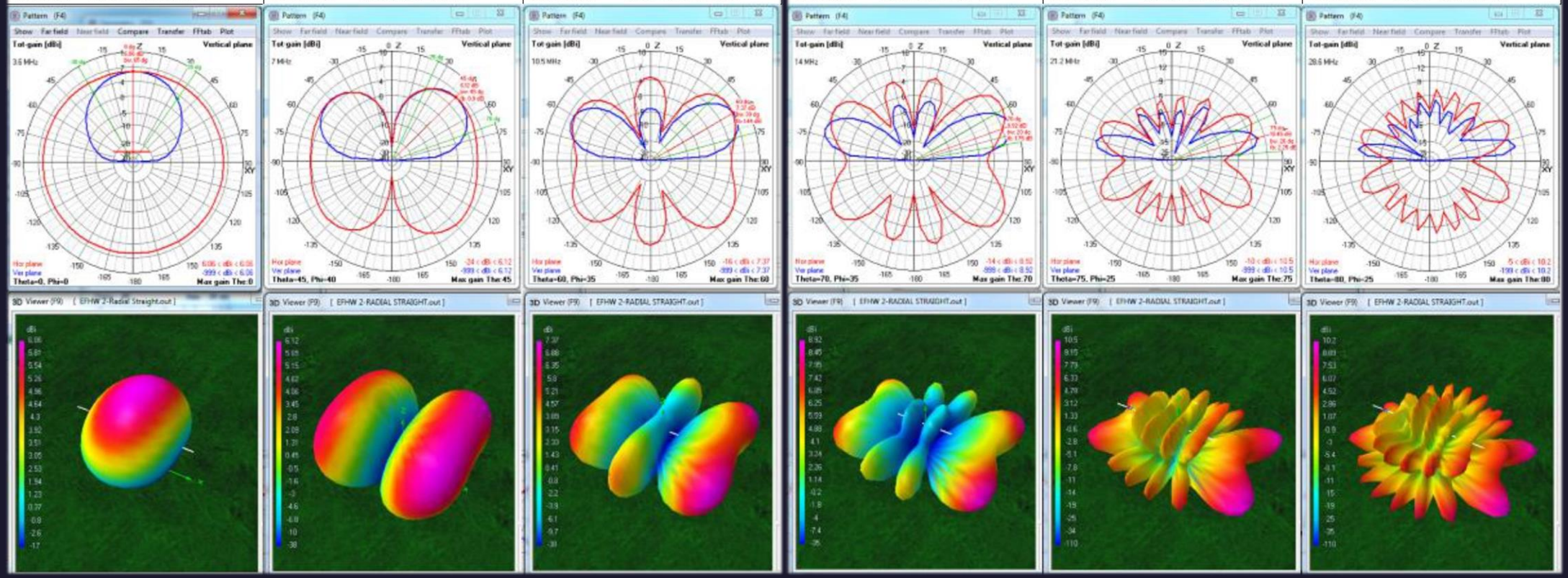
Dipole Harmonic Resonances



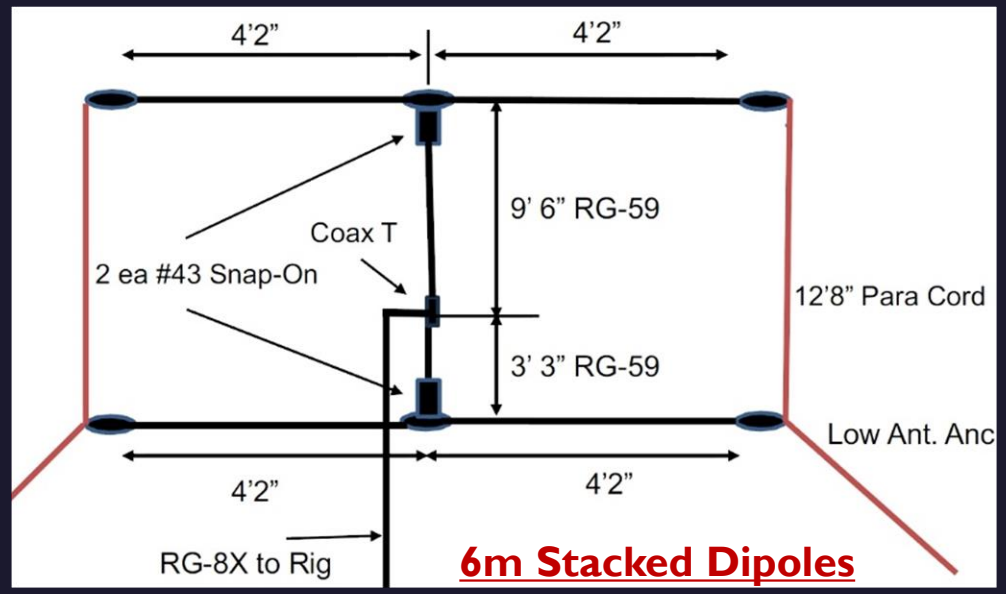
Dipole* Harmonic Radiation Patterns

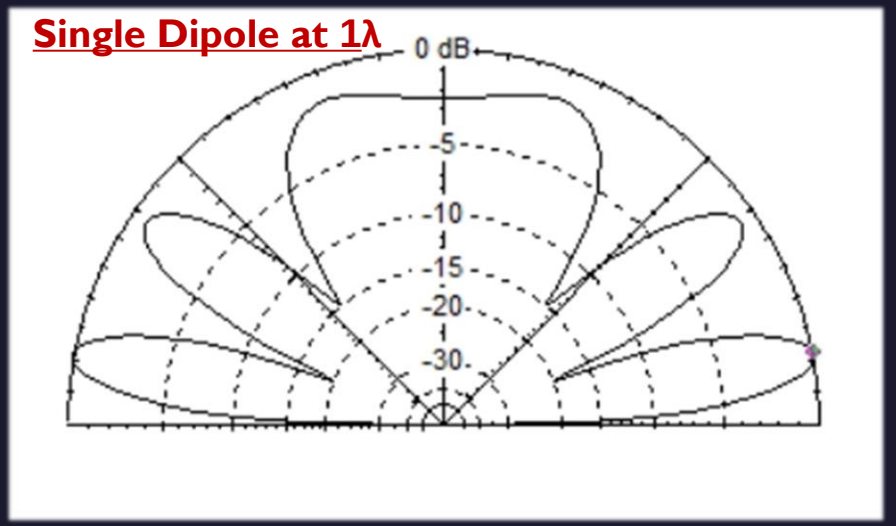
At 60 feet height

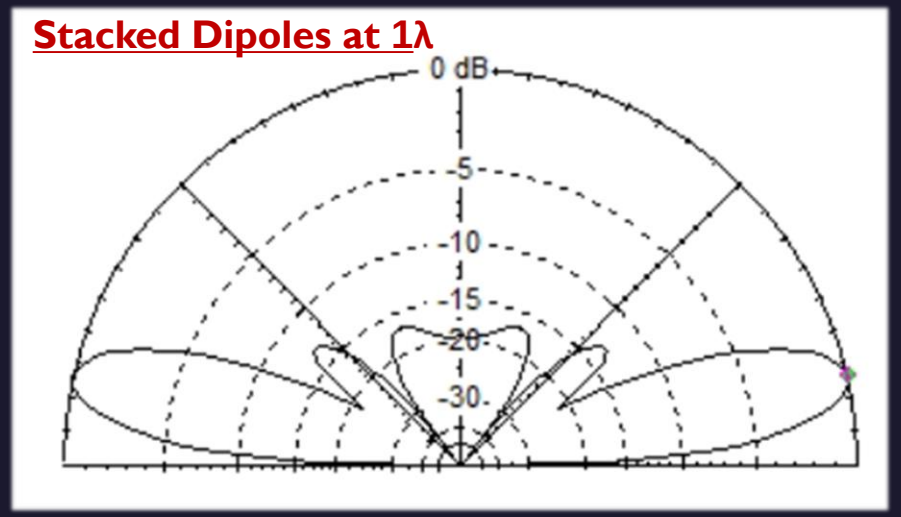
80m Fundamental	**40m** 2nd Harmonic	**30m** 3rd Harmonic	**20 m** 4th Harmonic	**15m** 6th Harmonic	**10m** 8th Harmonic
1 lobe 6.06 dBi at 0°	2 lobes 6.12 dBi at 50°	3 lobes 7.37 dBi at 60°	4 lobes 8.92 dBi at 70°	6 lobes 10.5 dBi at 75°	8 lobes 10.2 dBi at 80°



Stacked Dipoles – Great for High Bands

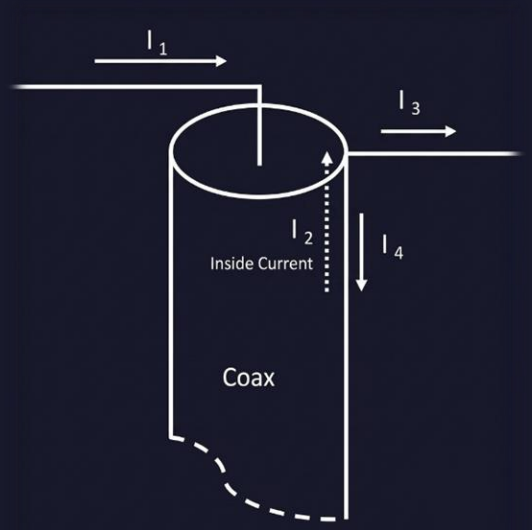






- Suppresses High Lobe at all installation heights
- Optimal spacing 0.6 to 0.75 λ
- Dipoles fed with 1/4 λ transformers (and 3/4 λ)
- Reverse one dipole feed due to 180° shift.
- Tuning procedure

Baluns and Common-Mode Chokes



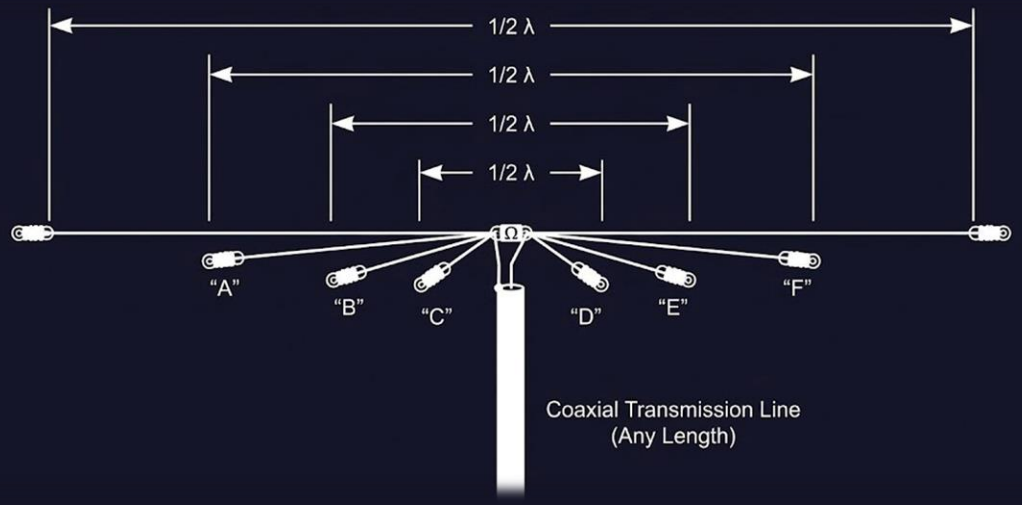
Coax has 3 conductors!

Types:

- Current Baluns (1:1, 4:1…)
- Voltage Baluns (avoid)
- Ferrite common-mode choke

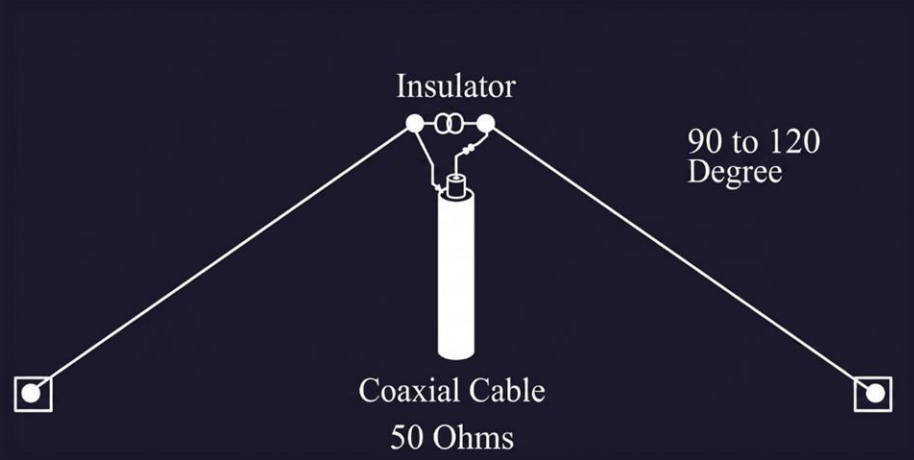
- Balanced and Unbalanced
- Feedline radiation, Noise Pickup, Distorted patterns, RF in the shack
- Baluns and CM Chokes stop the RF on the outside of the coax

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)

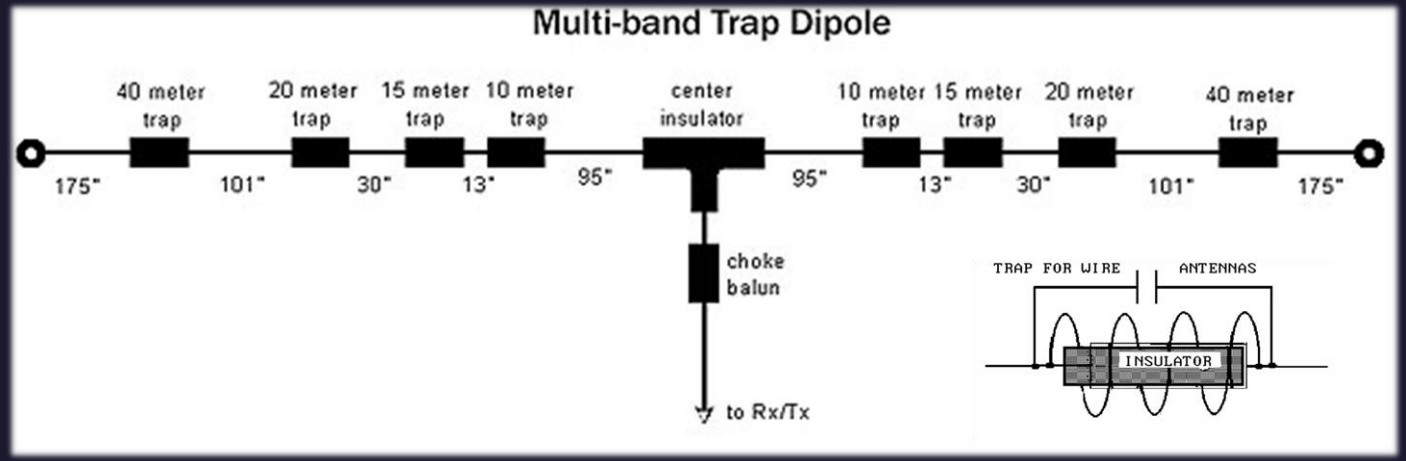
Inverted V – Bent Dipole

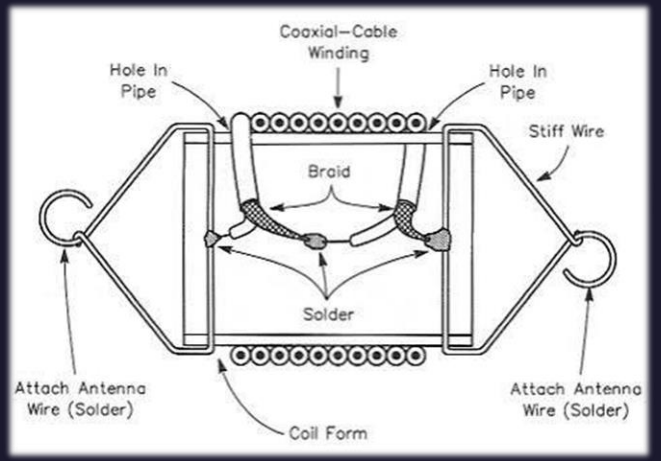


- Performance similar to dipole
- Single support structure, 90°-120° angle
- Feed-point impedance closer to 50Ω
- Radiation pattern becomes more omnidirectional
- Slightly lower gain than a flat dipole
- Excellent HF wire antenna: Easy to build, Efficient

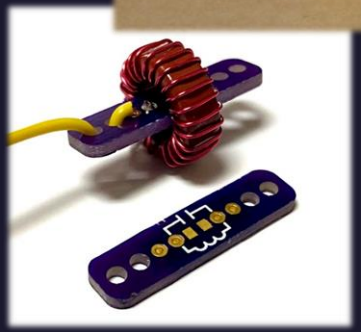
Multi-Band Inverted-V Fan

Trap Dipole – Electrically Isolate Sections



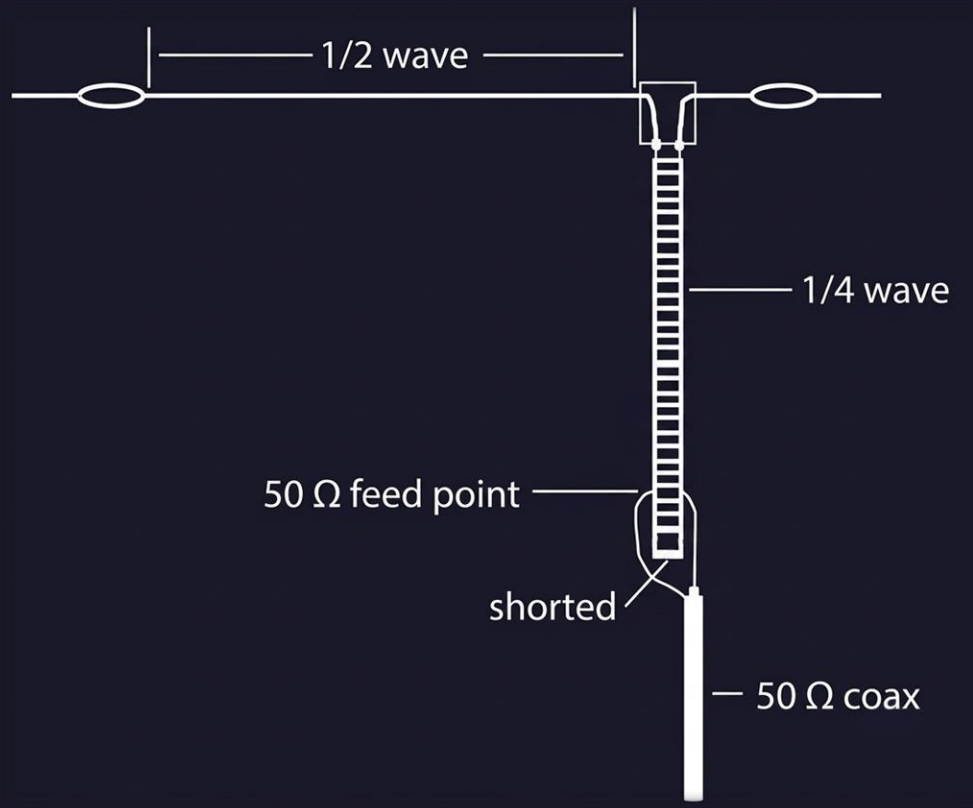


- Parallel Resonant Circuits as RF switches
- Narrower bandwidth, Trap losses, QRO issues
- Behaves like a Dipole
- Can be implemented as Inverted V
- Harder as DIY – need a way to tune the traps.
- HF Multiband Solution – not my favorite

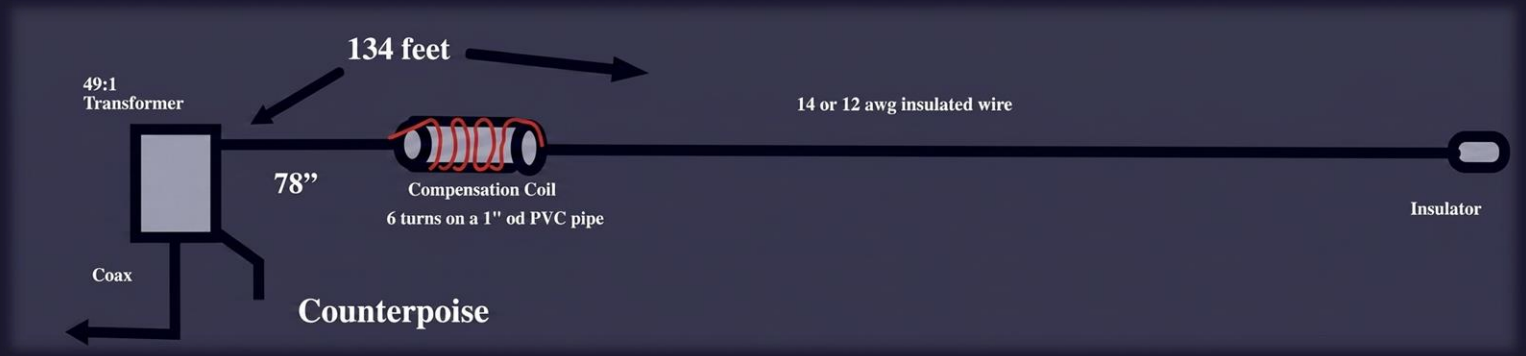


End-Fed Zepp Antenna

- End Fed single-band antenna
- Uses Ladder line as a ¼ λ matching section
- Low loss antenna
- Needs Balun or CM choke



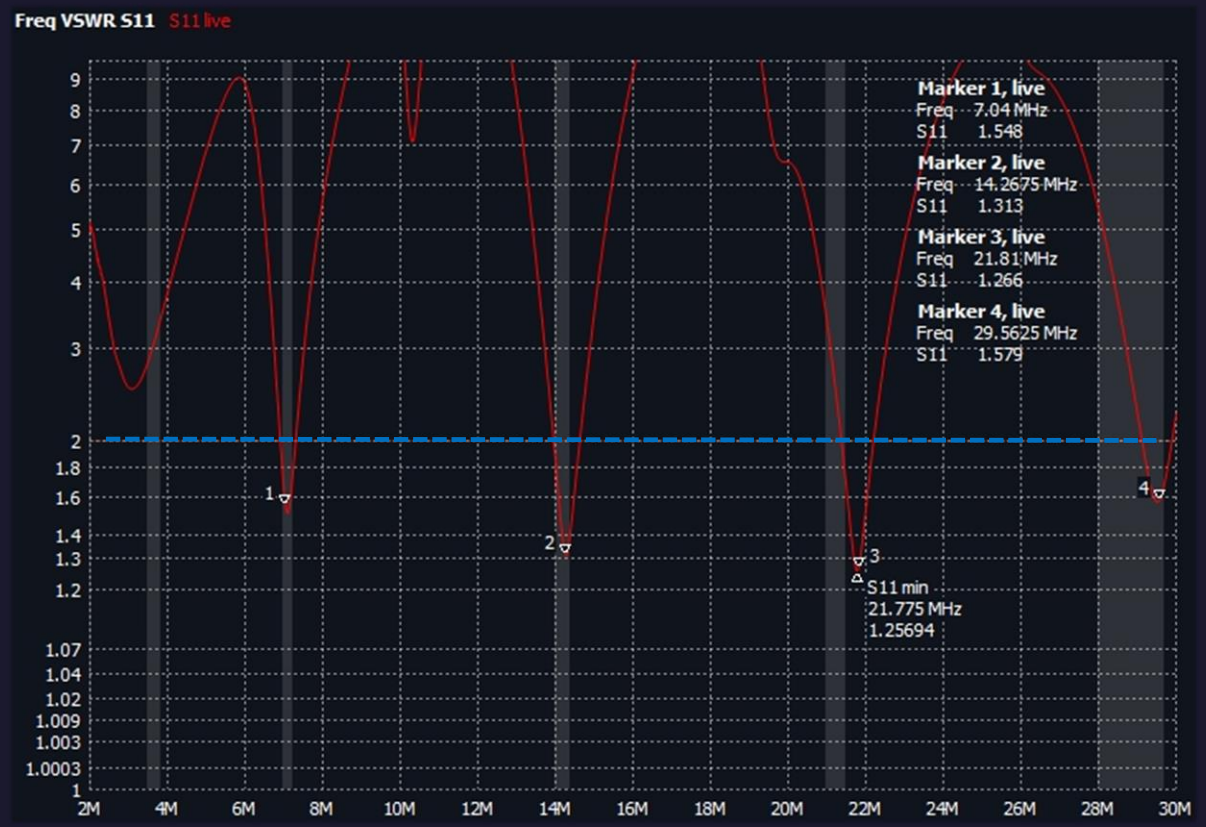
End-Fed Half Wave (EFHW)



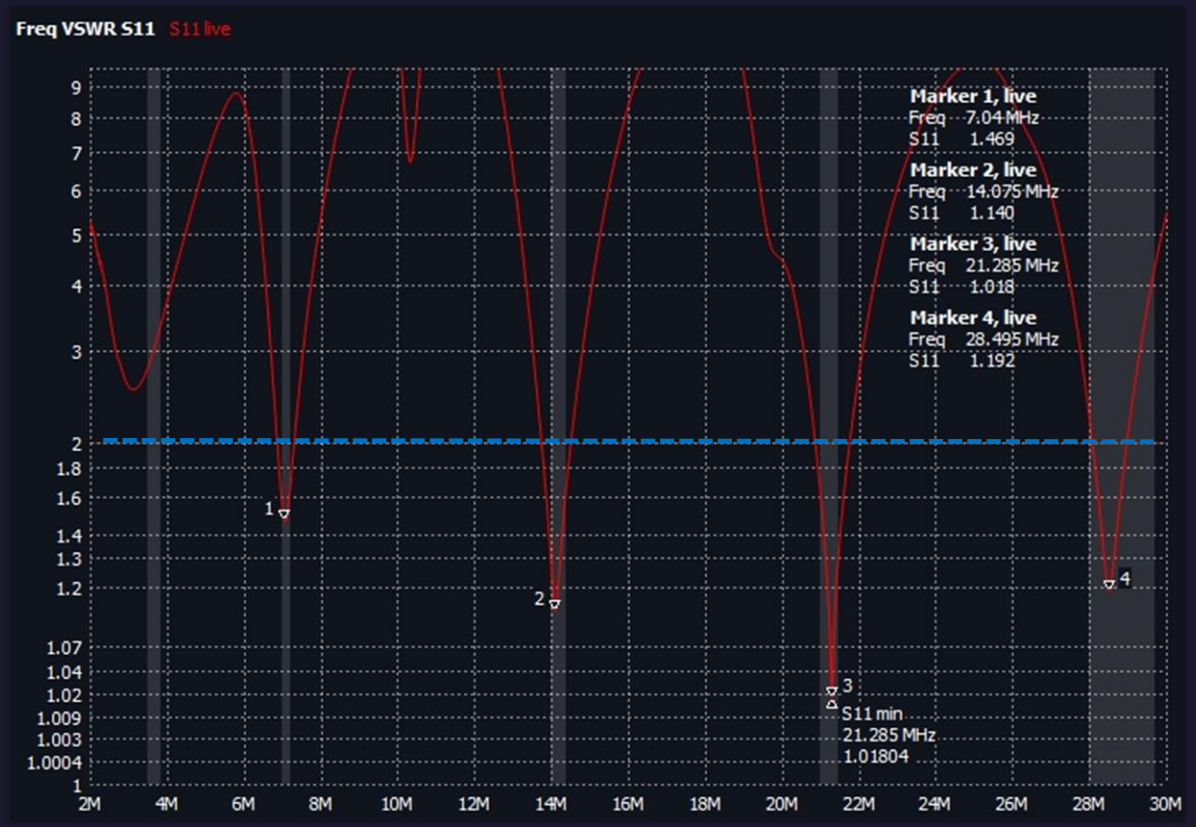
- Multi-Band Zepp - resonant on ALL ½ λ harmonics
- ~2500Ω feed-point, needs 49:1 wideband transformer
- Needs Counterpoise! Needs good CM Choke!
- Complex Radiation pattern on higher harmonics
- Can be implemented as Inverted V, Inverted L, etc.
- Tuning: Needs Loading Coil to optimize multi band resonance
- Very popular Beginner HF Multiband Solution – not QRO friendly

EFHW Compensation Coil Effect

Without Coil



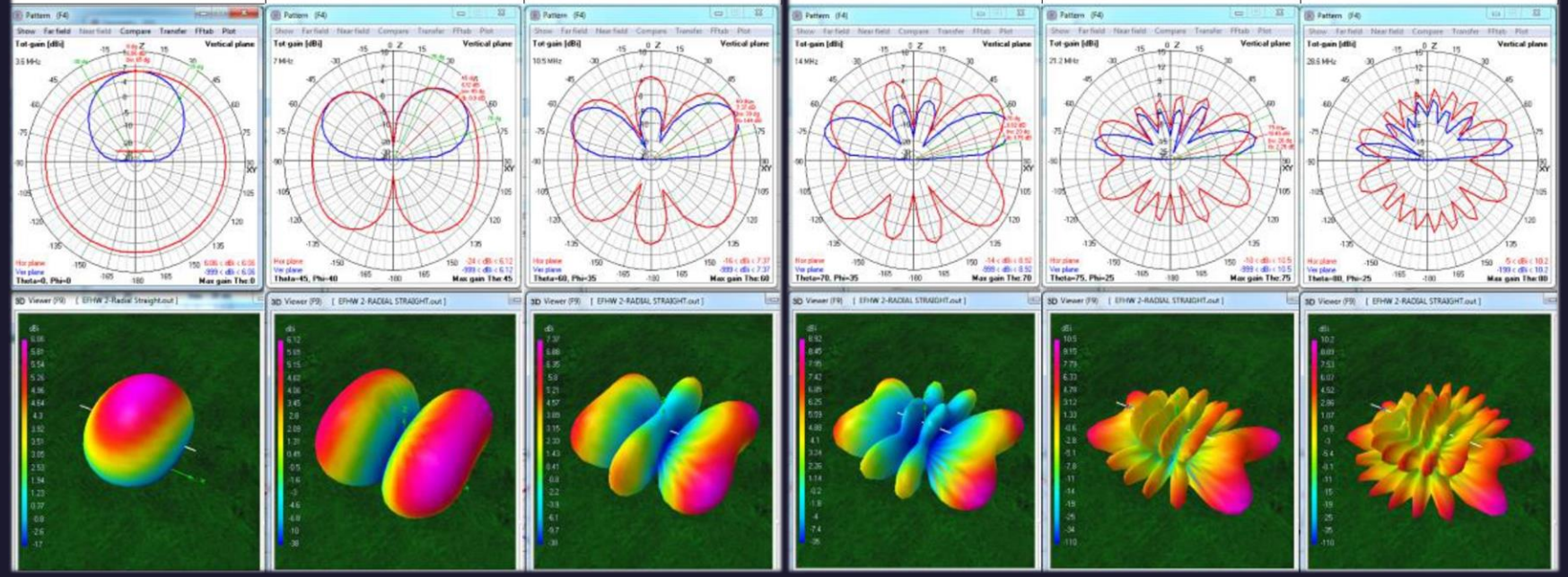
With 1.5uH Coil

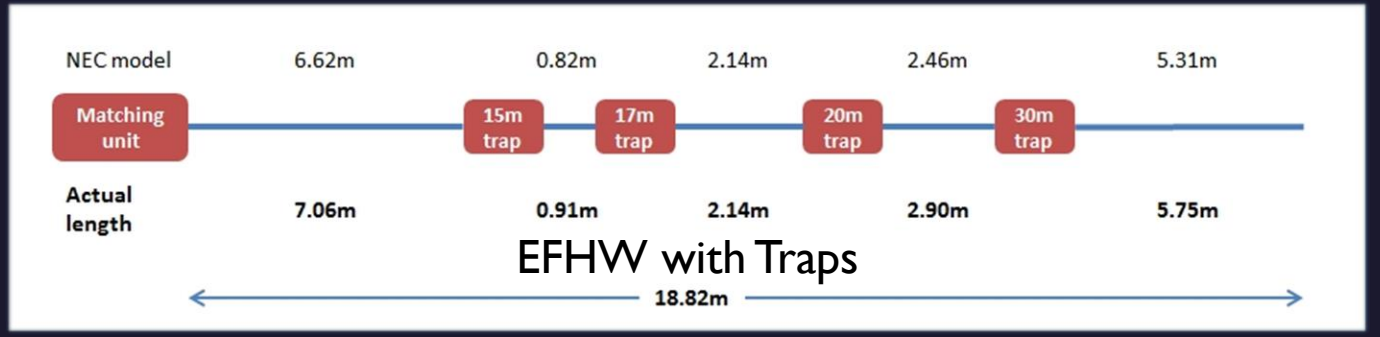


EFHW Radiation Patterns

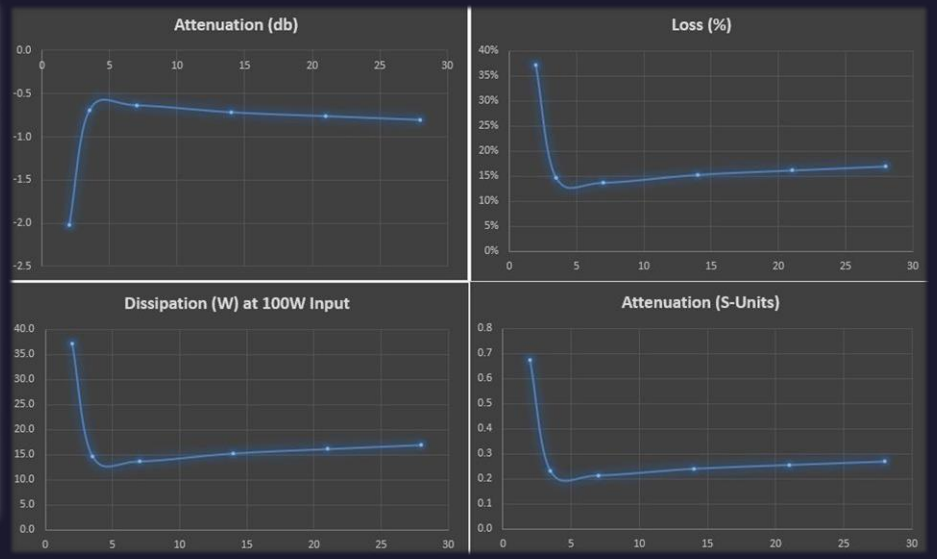
At 60 feet height

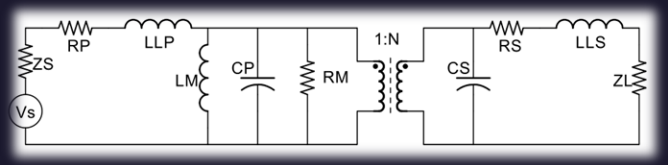
80m	Fundamental	**40m**	2nd Harmonic	**30m**	3rd Harmonic	**20 m**	4th Harmonic	**15m**	6th Harmonic	**10m**	8th Harmonic
1 lobe	6.06 dBi at 0°	2 lobes	6.12 dBi at 50°	3 lobes	7.37 dBi at 60°	4 lobes	8.92 dBi at 70°	6 lobes	10.5 dBi at 75°	8 lobes	10.2 dBi at 80°





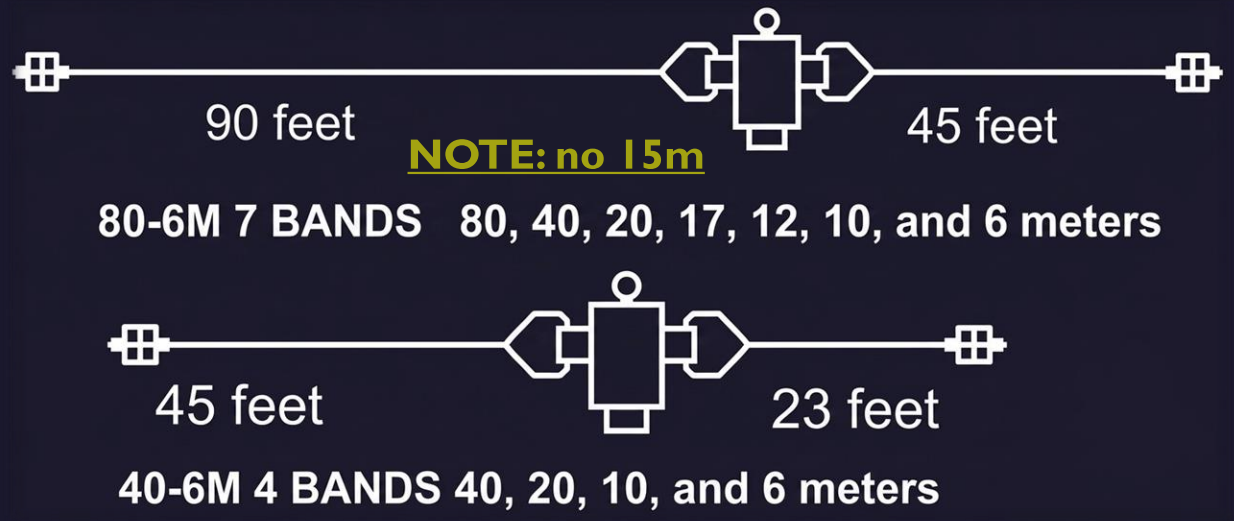
EFHW Unun (49:1 Transformer)





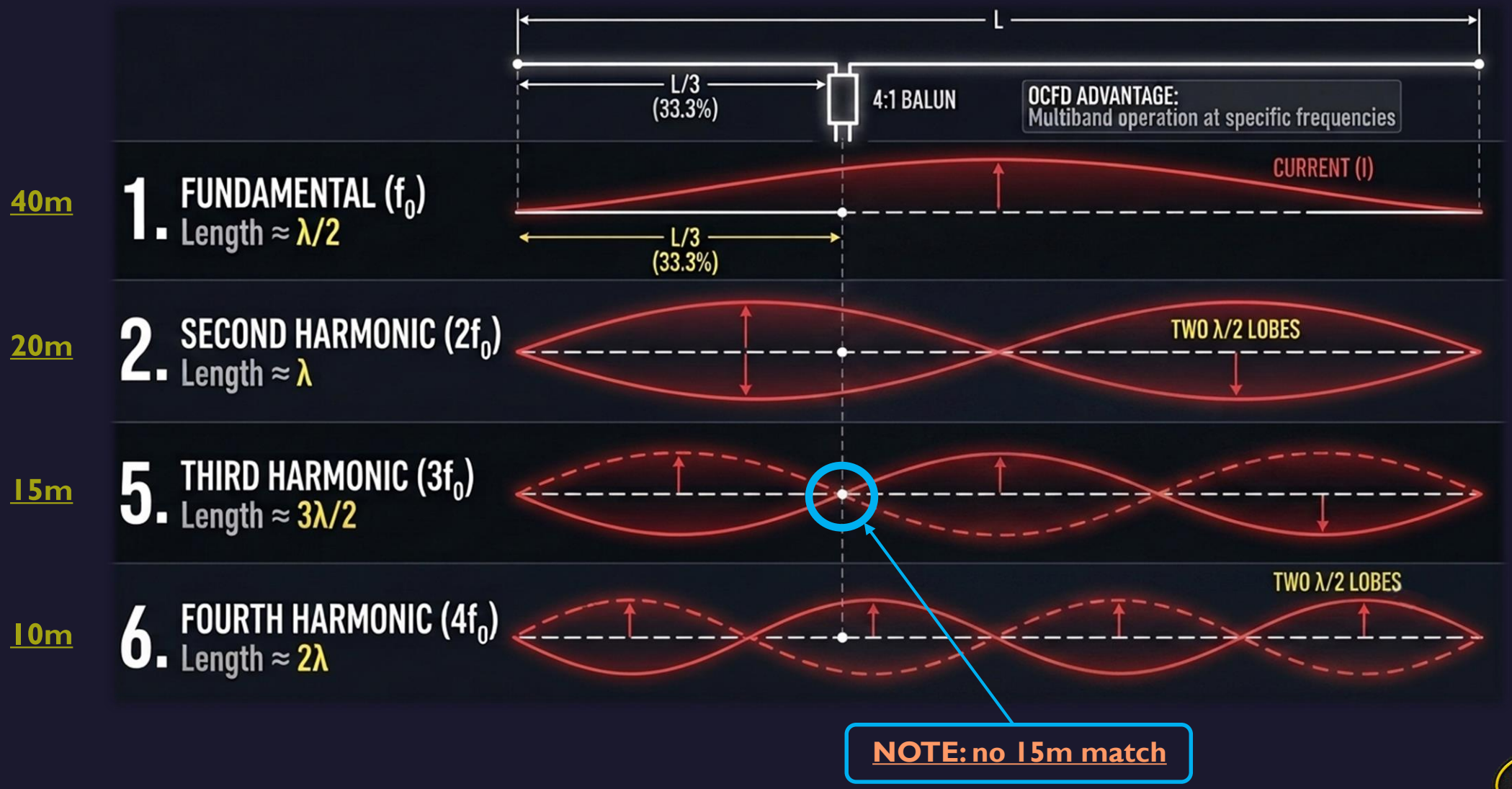
- Limiting system component
- Many designs in the web – most of them unfit
- Better to buy a reputable device
- DO NOT OMIT GOOD BROADBAND CM CHOKE!

Off-Center-Fed Dipole (OCFD)

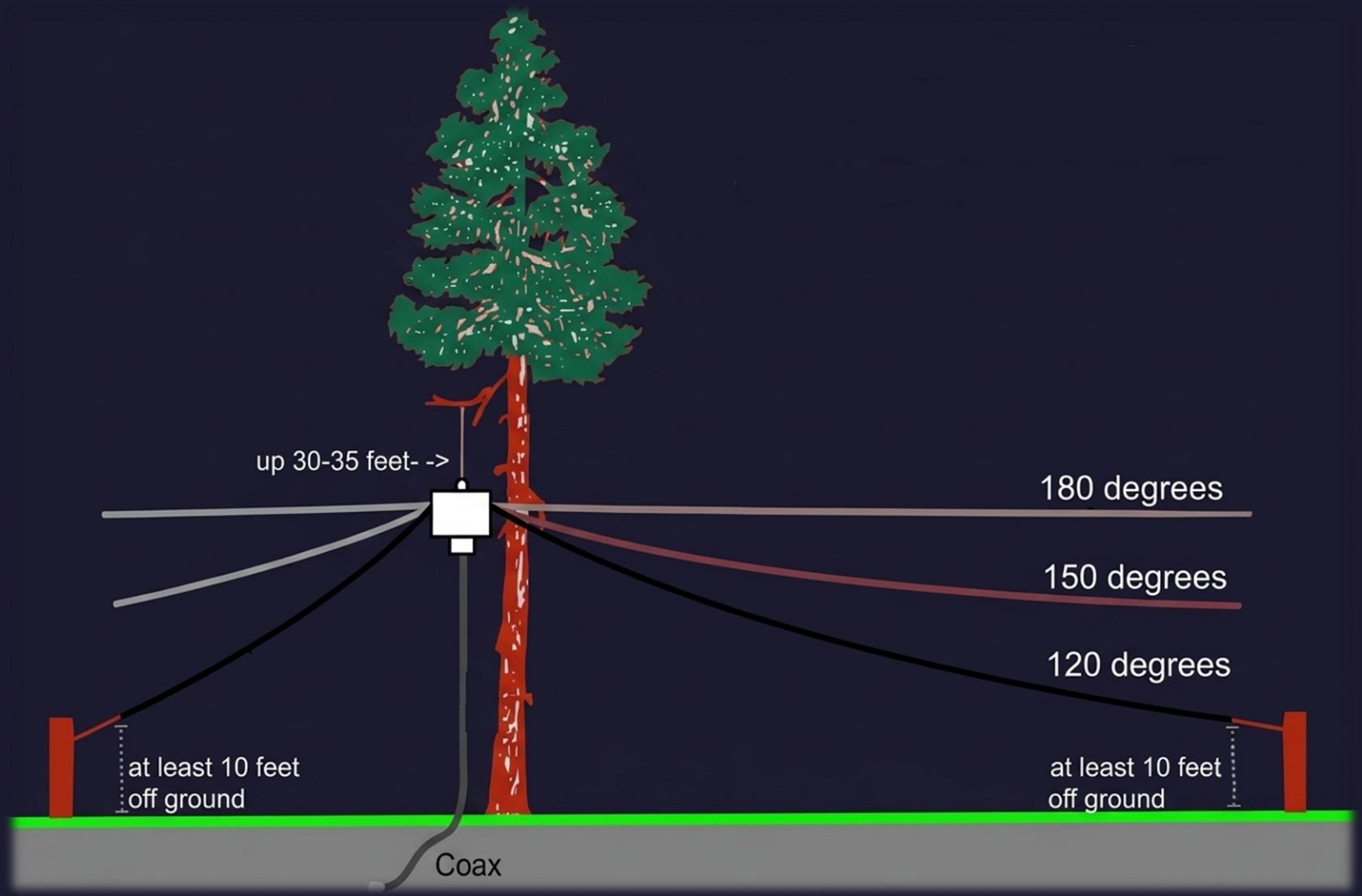


- Covers multiple HF bands with one antenna
- Fed 33% (28-36%) of length from one end.
- ~200Ω (300Ω) feed, needs 4:1 wideband transformer
- Often used without a tuner on its **primary** bands
- Complex Radiation pattern on higher harmonics
- Very popular HF Multiband Solution

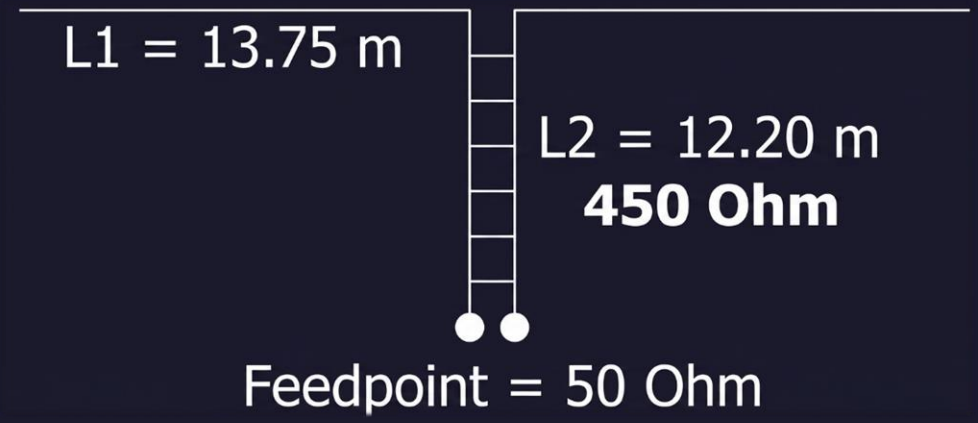
Off-Center-Fed Dipole Resonance



Off-Center-Fed Dipole Installation



ZS6BKW Dipole



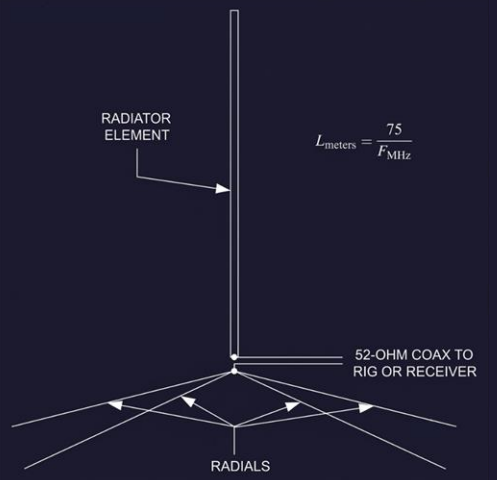
- Modified G5RV antenna
- ½ λ dipole with integral 450 (or 300) ohm ladder line
- Ladder line acts as a matching system and/or a radiator
- Not resonant on all bands, but presents low VSWR (not the same)
- Low VSWR on 40, 20, 17, 12, 10m – no 80 and15m without tuner
- Needs 1:1 Balun or CM choke – QRO Friendly

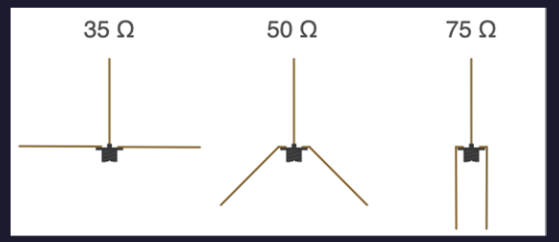
Vertical Antennas - Why Use a Vertical?

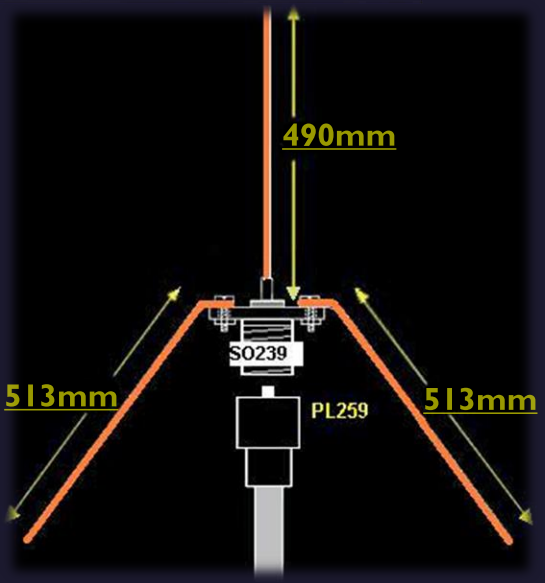
- Low takeoff angle, but lower gain
- Implementations: ¼ λ, ½ λ, 5/8 λ
- Best used on low bands
- Higher receive noise (QRN & QRM)
- Ground losses
- Often Misunderstood

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





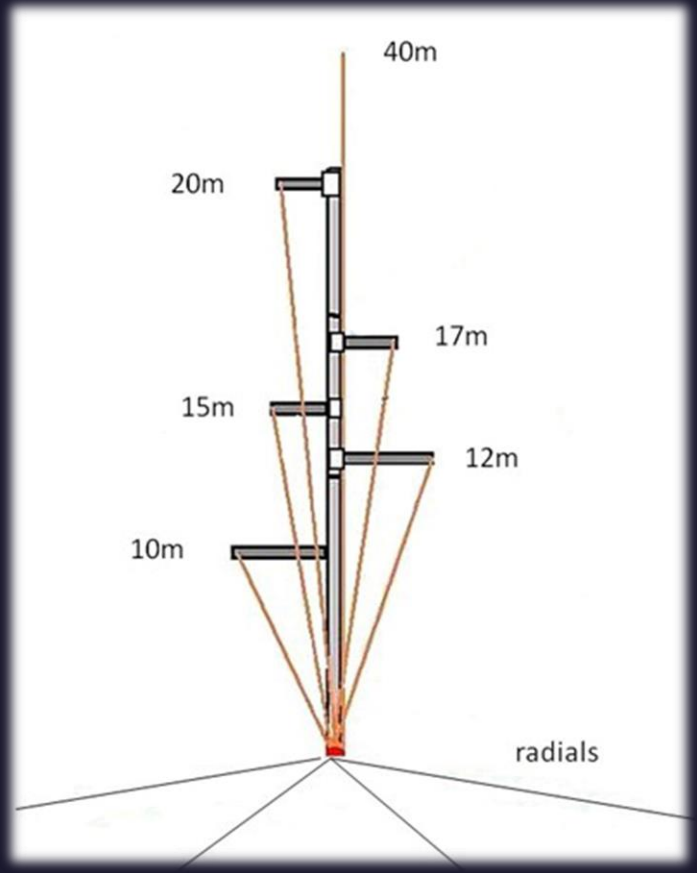


2m DIY Ground Plane

23cm DIY Ground Plane

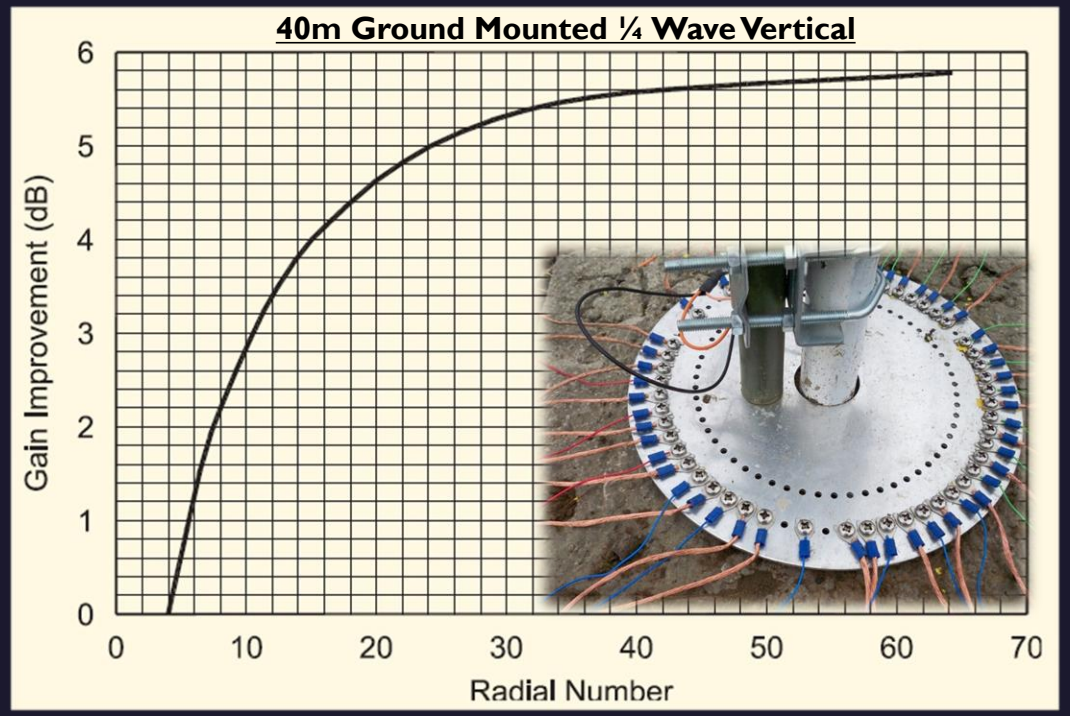
Fan Vertical (DX Commander)

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



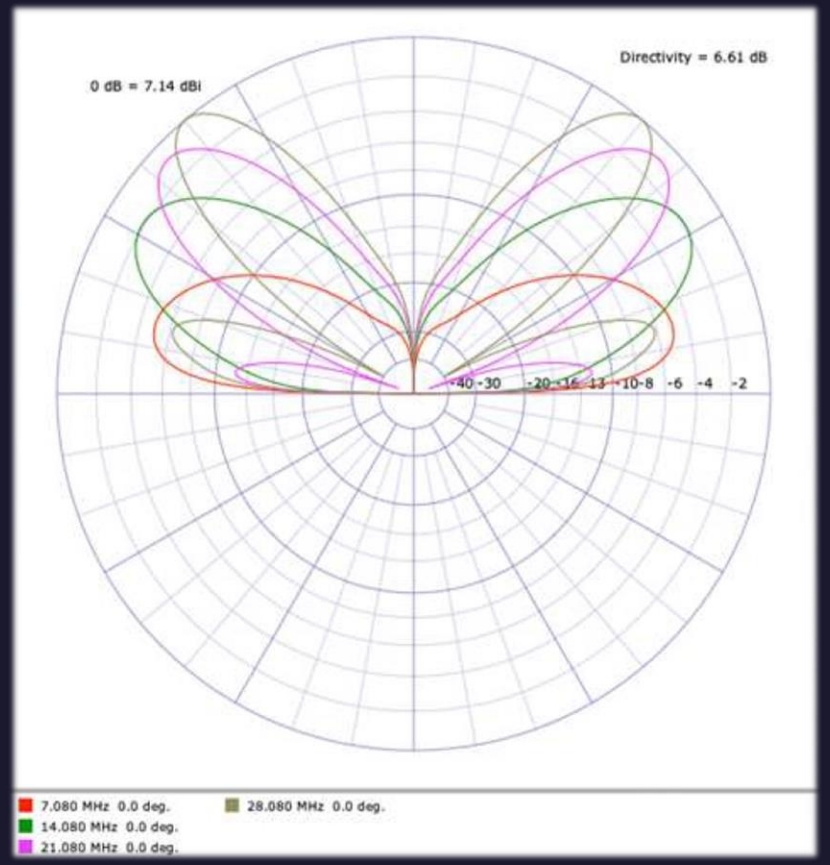
About Radials…

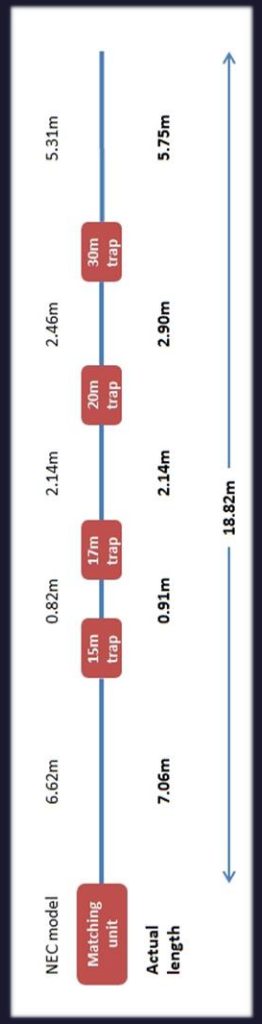
- **Vertical's most important part!**
- The radial field is half the antenna
- **GND Radials:** More is better (32+)
- **Elevated Radials:**
  - Tuned ¼ λ Radials for each band
  - 1 elevated = 8 ground radials
  - 1 ft. or more above ground
  - Much lower ground loss
  - Roof Installations



End Fed (Half Wave) Verticals

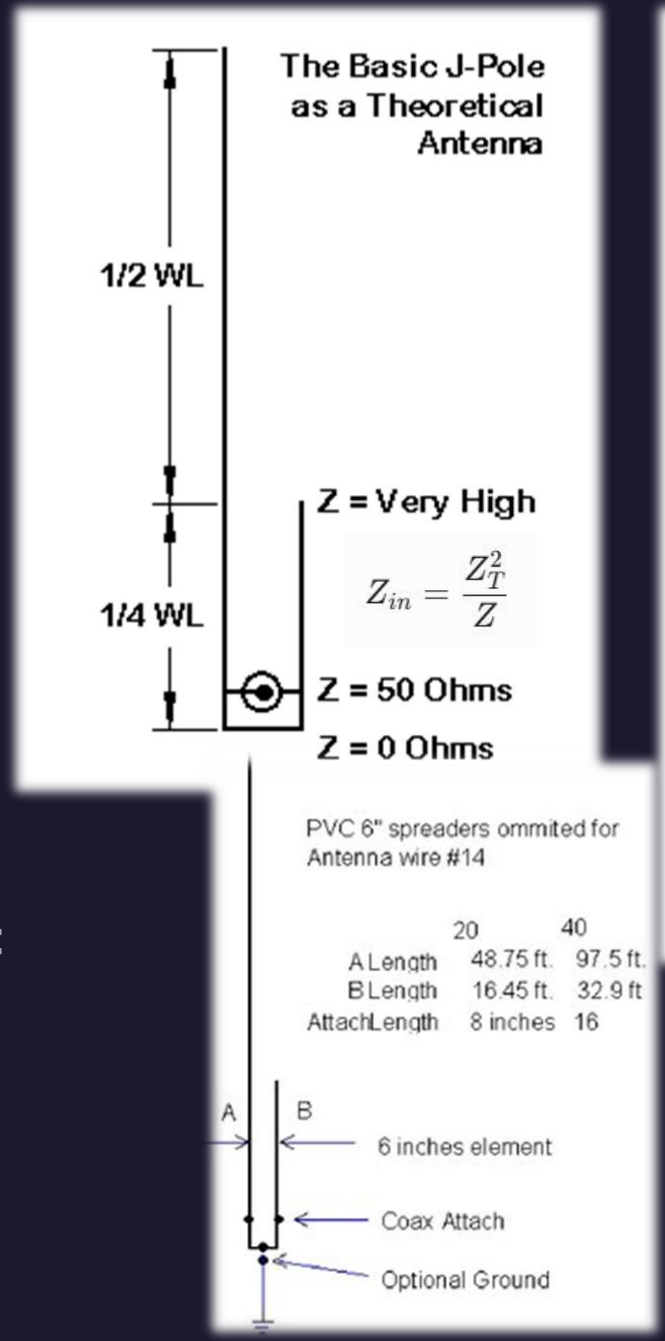
- Single-Band vertical EFHW Dipole
- Multi-Band using “Traps” or linear loading
- Cannot be made into a DIY Fan!
- No radials, only small counterpoise(s)
- Commercial Examples:
  - Cushcraft R8
  - Hustler 6BTV
  - Hy-Gain AV series

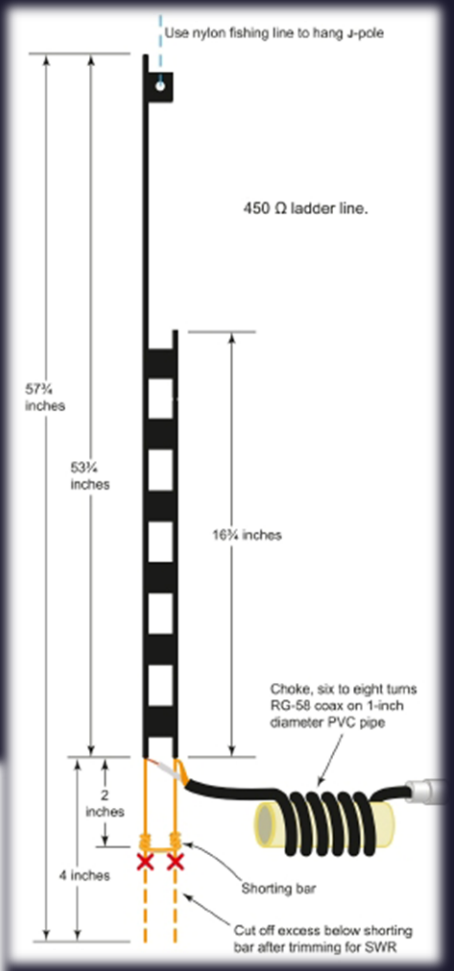


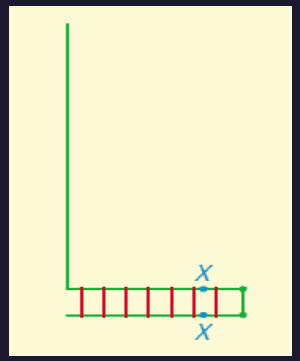


J-Pole Verticals

- 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!

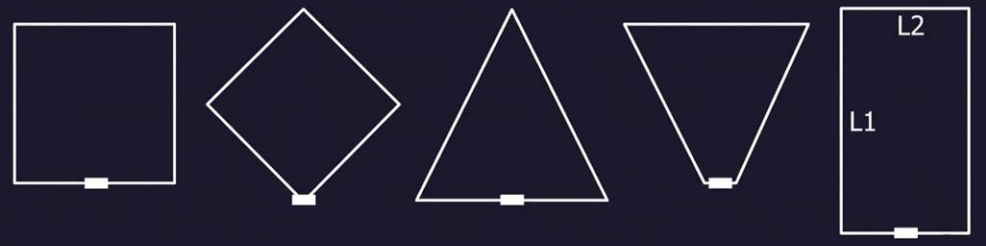


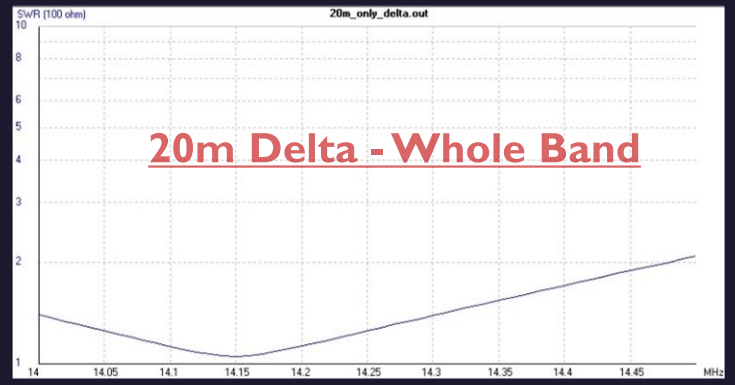


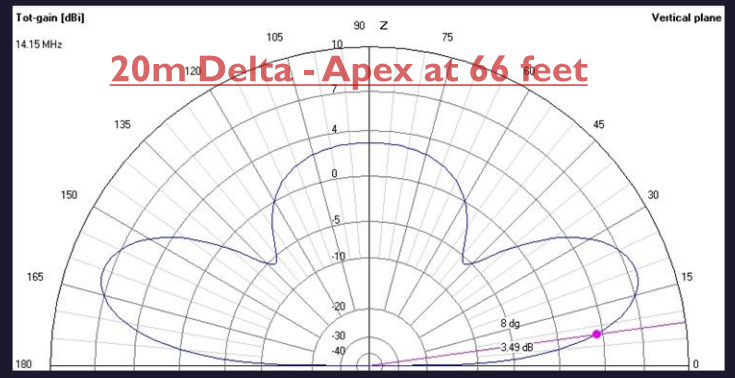


Full Wave Vertical Loop Antennas

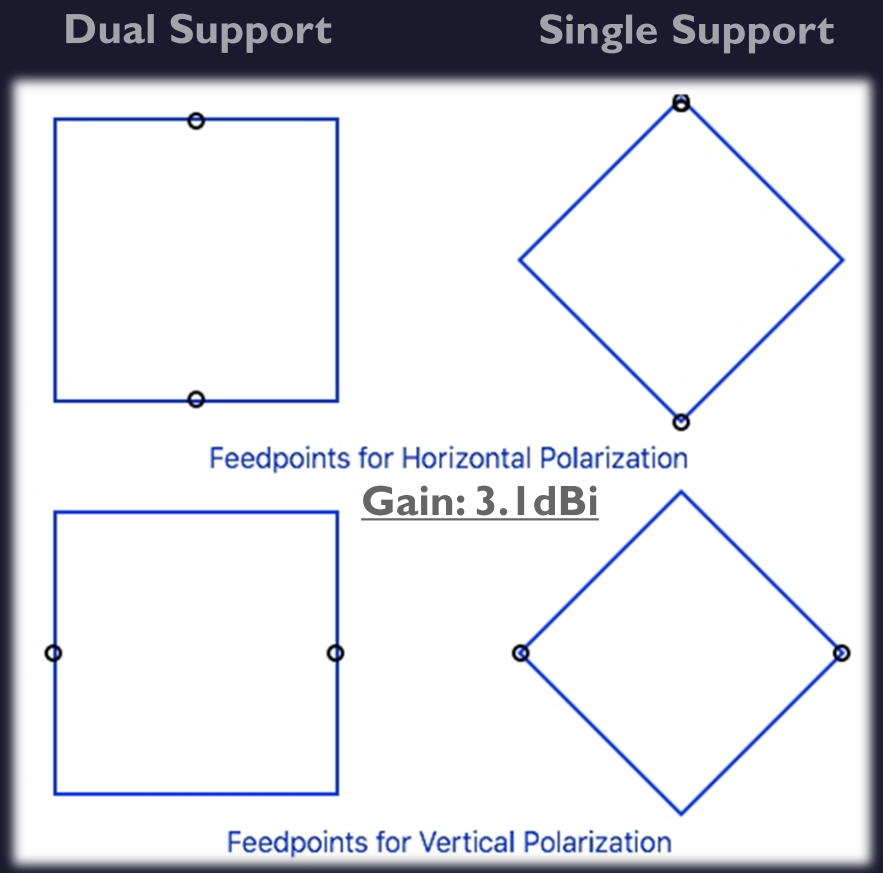
- Higher gain than Dipole (1.4dBd)
- Very quiet (1-2 S-units less QRN)
- Multi-Band possibilities
- ~110 ohm feed-point (2:1 Balun)
- Lower take-off angle than Dipole
- Selectable polarization via feed-point



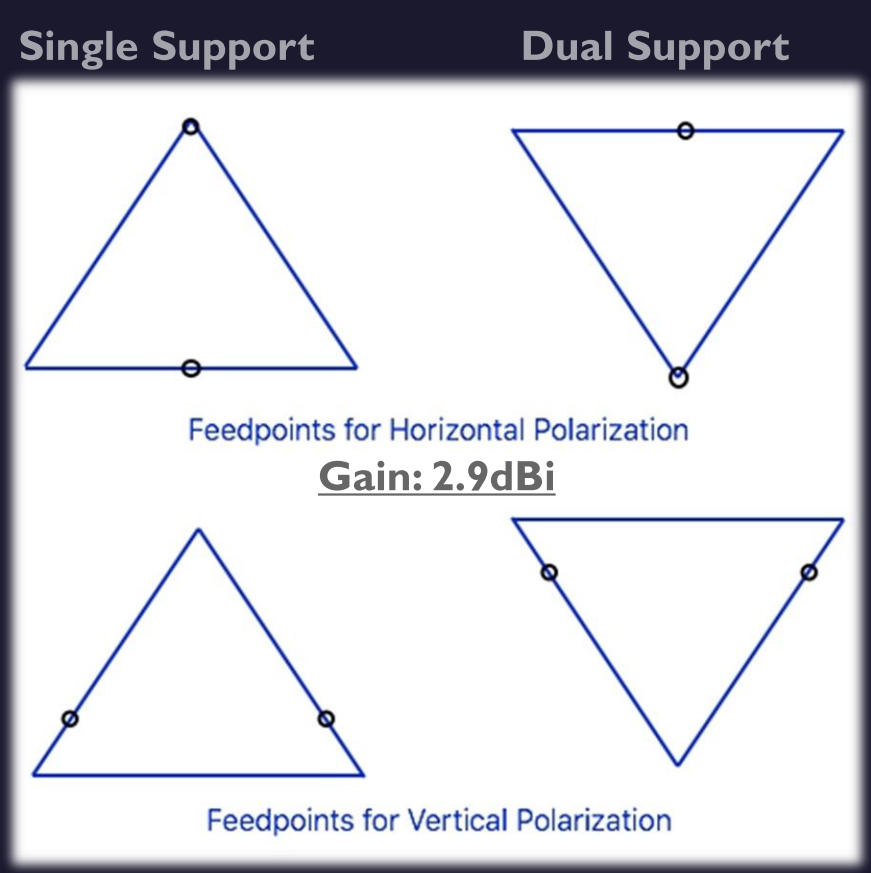




Loop Antenna Variations



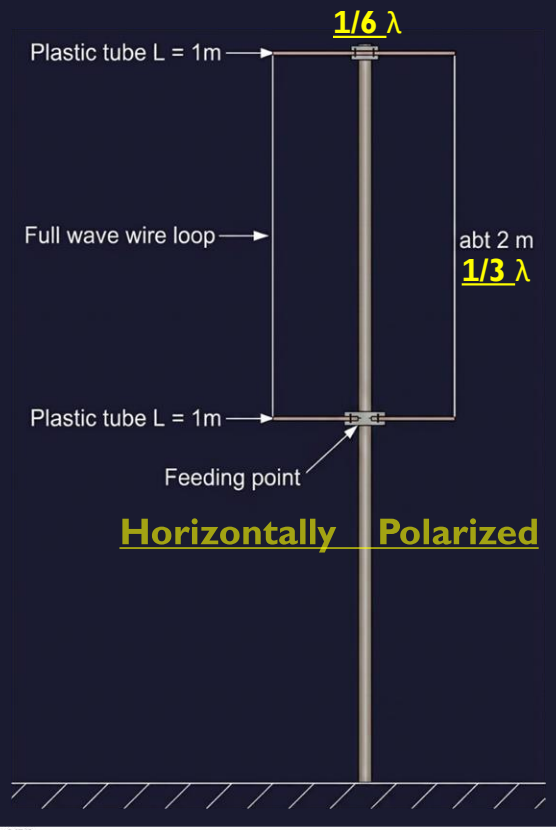
Square Loops

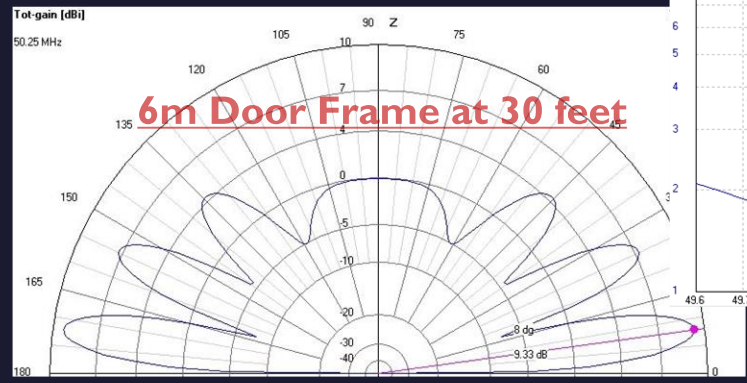


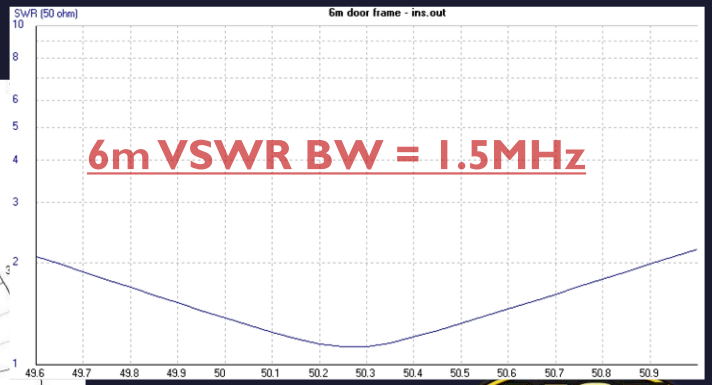
Delta Loops

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



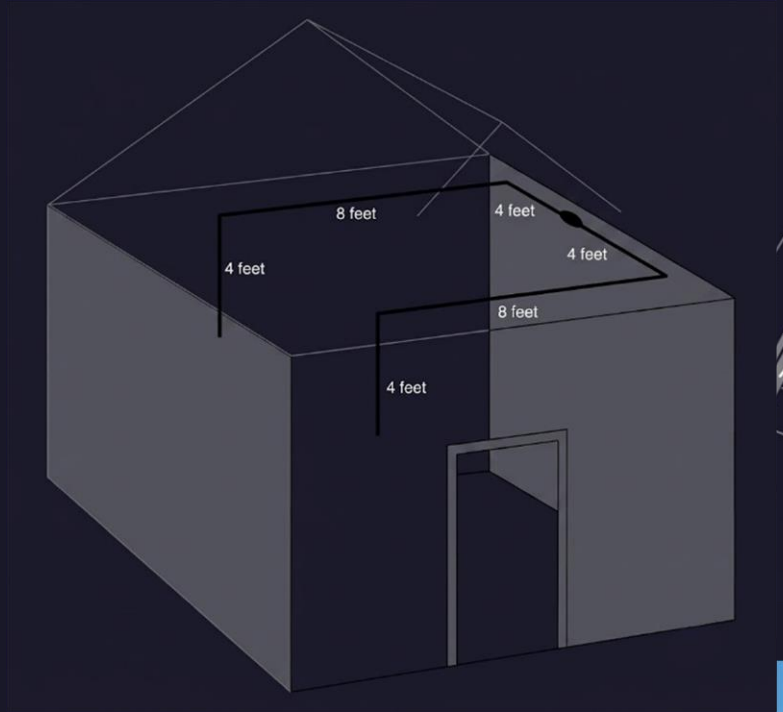




Antennas for HOA and Restricted Properties

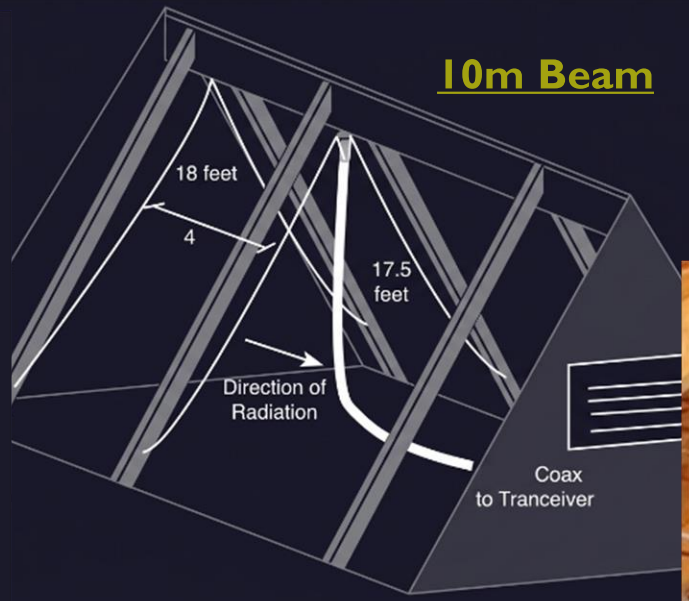
- **Many amateurs face restrictions on:**
  - Towers
  - Visible antennas
  - Roof-mounted structures
  - Permanent outdoor installations
  - Property modifications
- **The good news:**
  - Almost every property can support some form of HF antenna.

Attic and Indoor Ideas

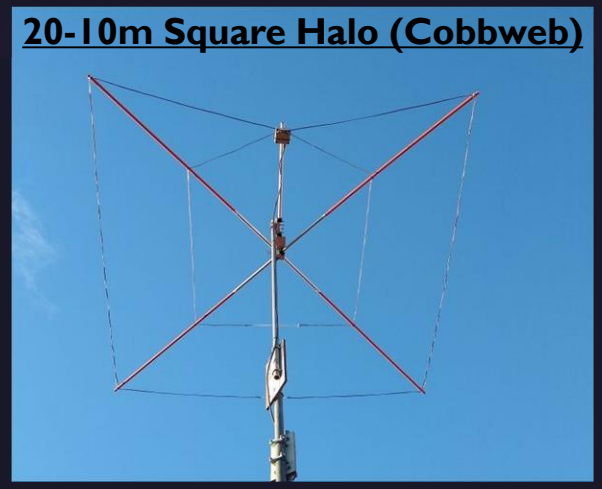


Multi-Band Ceiling/Attic Dipole

10m Beam



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" , ½" and ¾" (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

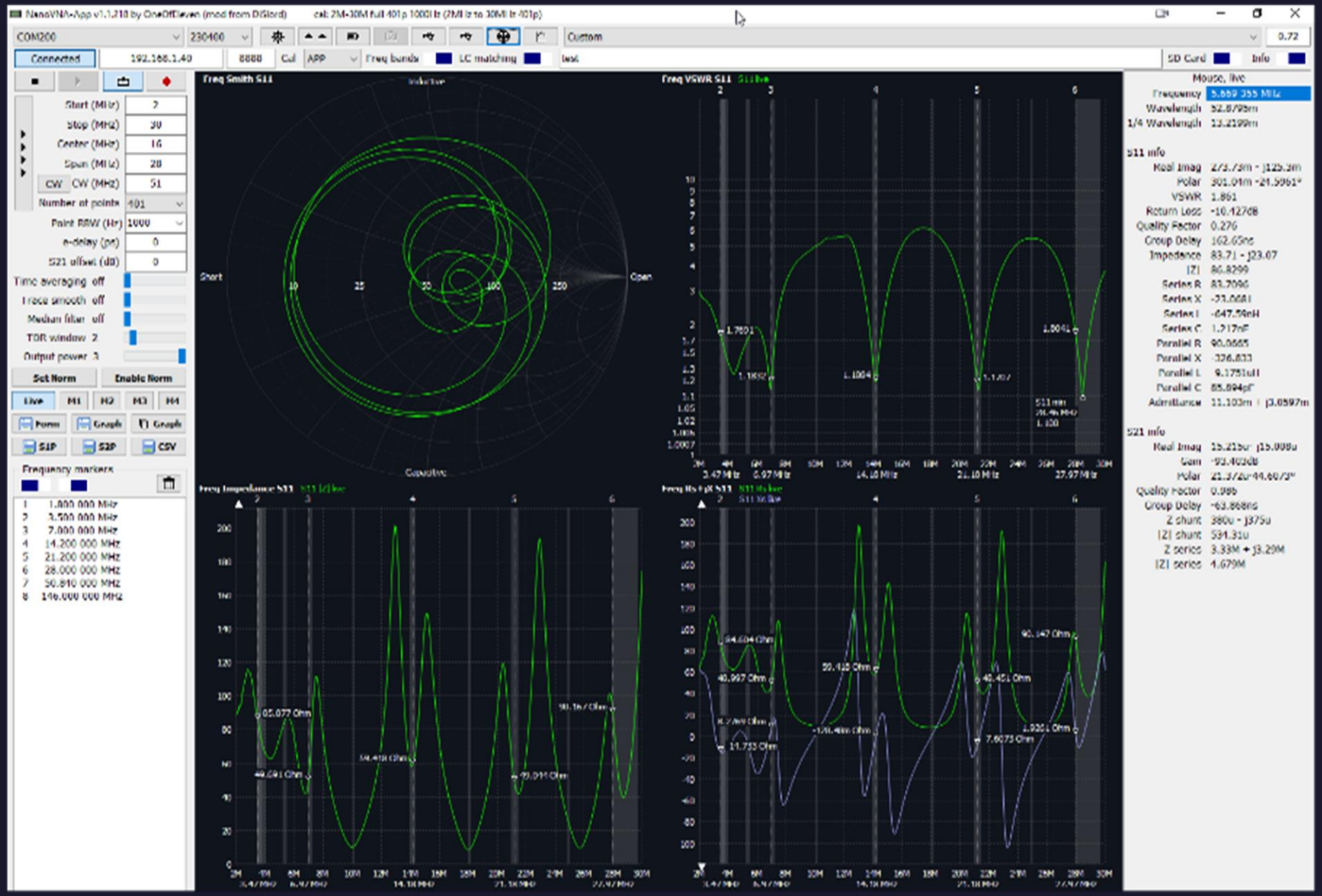
50kHz -3GHz, $125

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
AI2F