

# Basic Practical Antennas

## Welcome to Ham Radio University 2023!

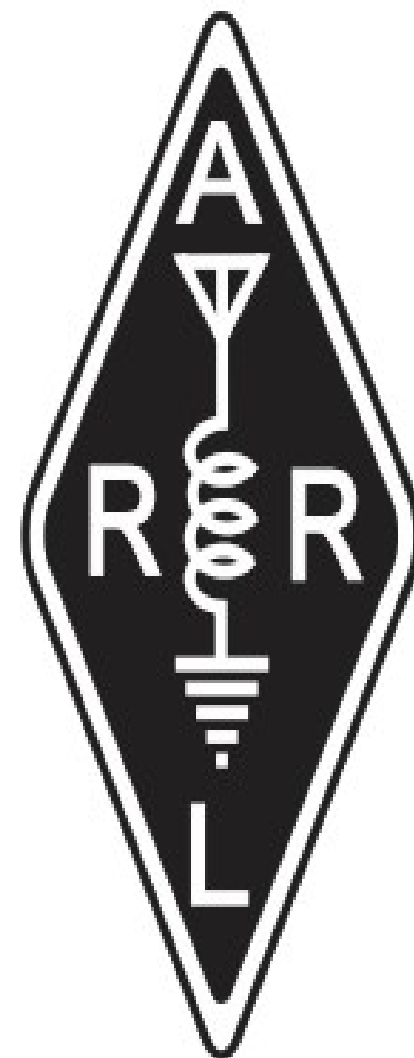
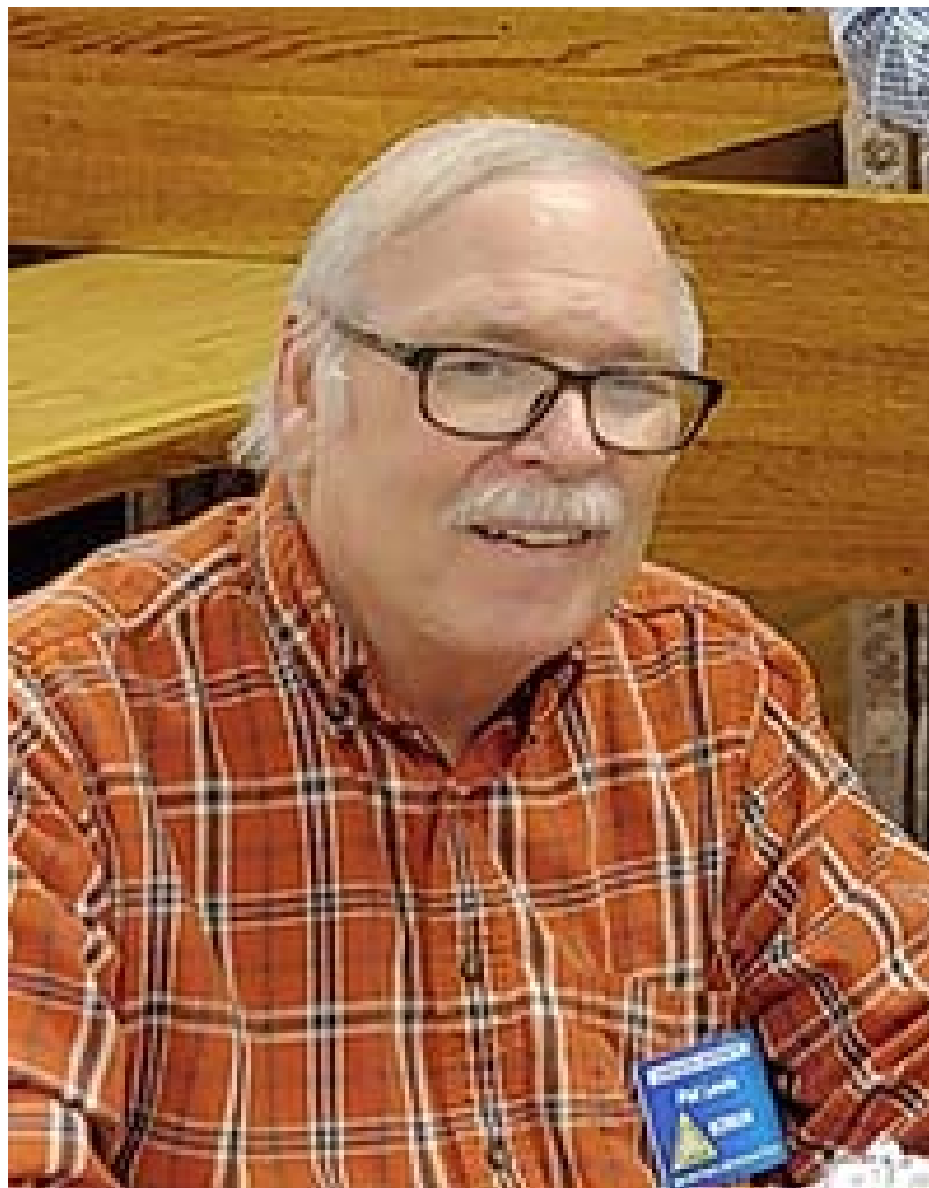
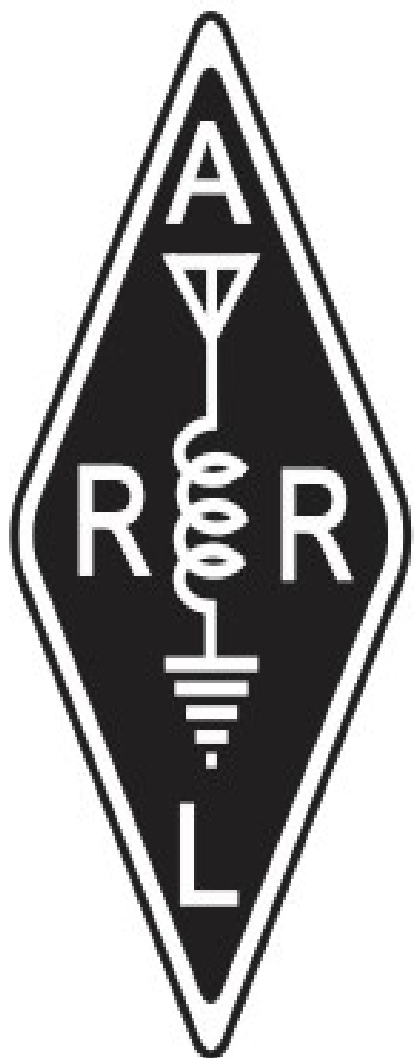
### HAM RADIO UNIVERSITY



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## 2023

## Our 24th Year!



Dedicated to the Memory of  
**Phil Lewis, N2MUN**  
Founder of Ham Radio University

- Your ham license allows you to do much more than just operate a radio.
- You can build, operate, and maintain your own equipment (on ham bands).
- No other radio service allows you to do this.
- Most hams have built, or will build at least one antenna. You can, too.

UNITED STATES OF AMERICA  
FEDERAL COMMUNICATIONS COMMISSION  
AMATEUR RADIO LICENSE

KC2KY

HEFT, NEIL M  
CENTEREACH, NY 11720

FCC Registration Number (FRN): 0009742453

Special Conditions / Endorsements

NONE

Grant Date	Effective Date	Print Date	Expiration Date
10-03-2017	10-03-2017	10-03-2017	12-18-2027

File Number	Operator Privileges	Station Privileges
0007944403	Amateur Extra	PRIMARY

**Let's Get Started!**

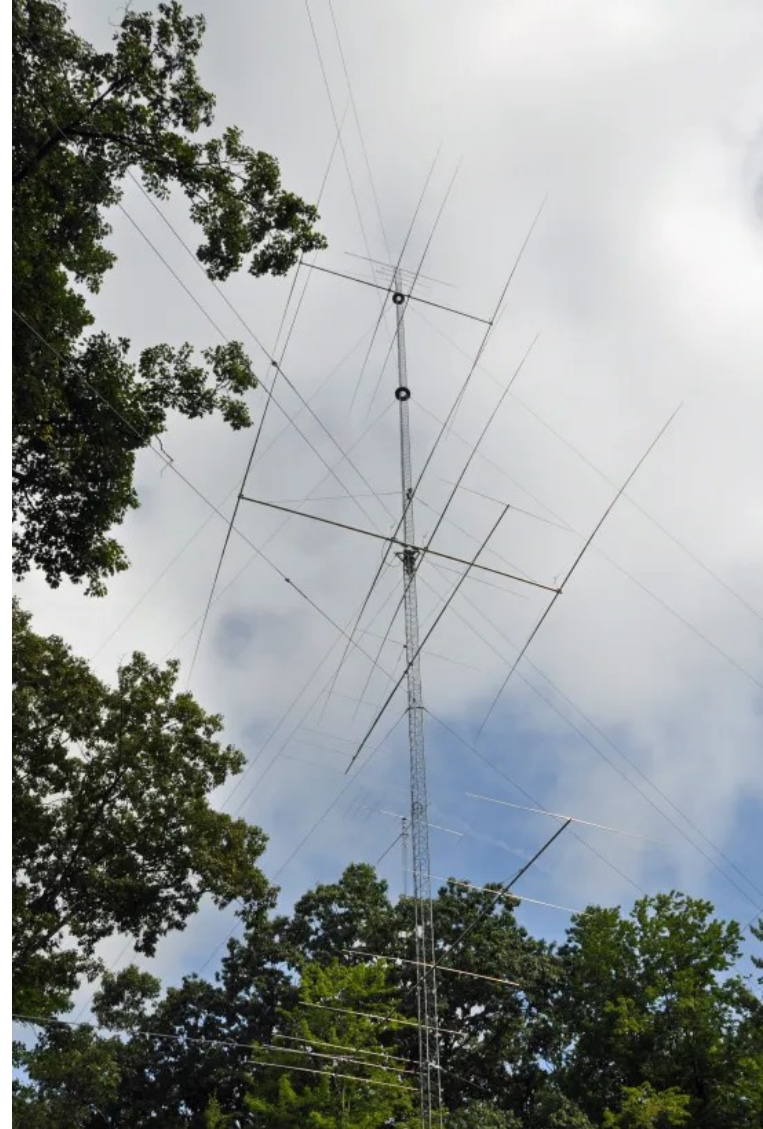
THIS LICENSE IS NOT TRANSFERABLE

\_\_\_\_\_  
(Licensee's Signature)

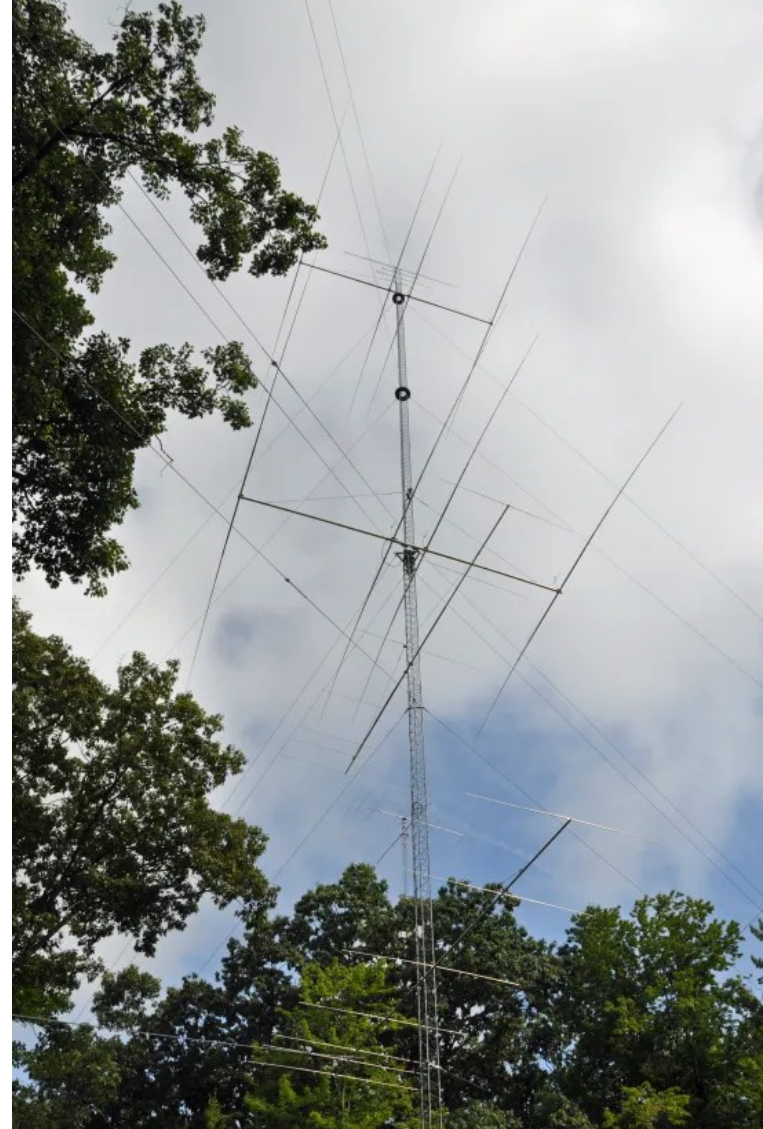
FCC 660 - August 2021

Cut Along This

# Three Things These Two Antenna Installations Have in Common

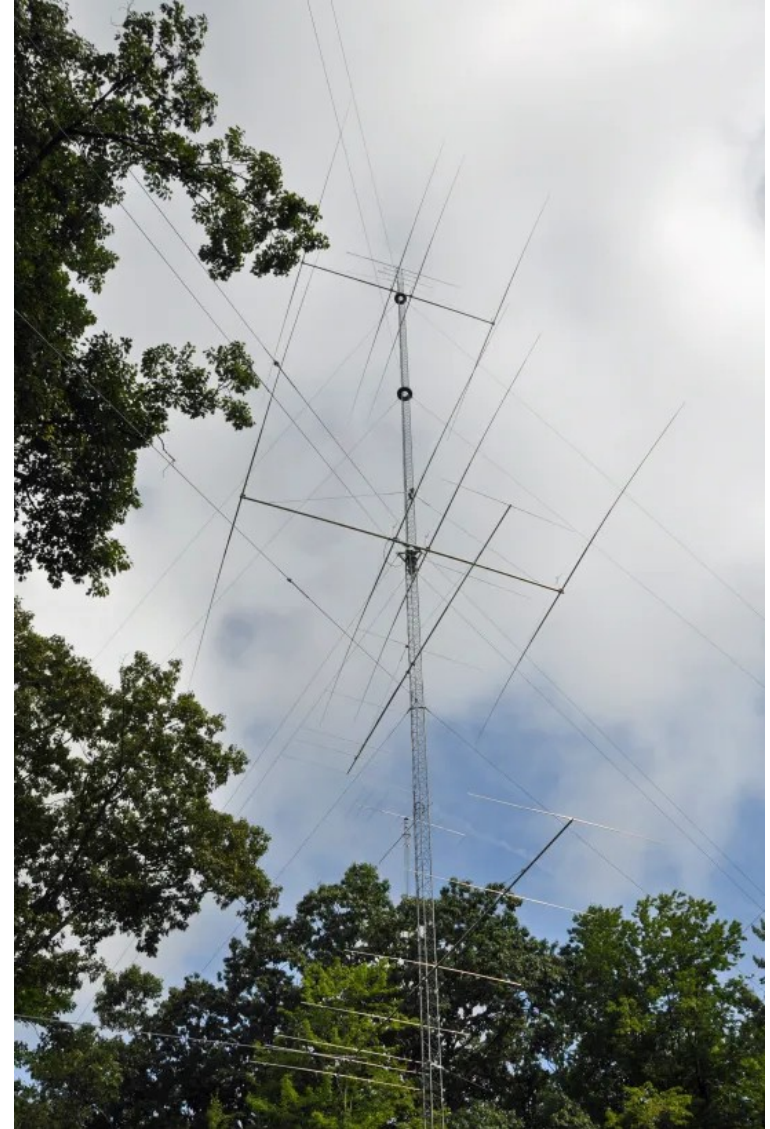


# Three Things These Two Antenna Installations Have in Common



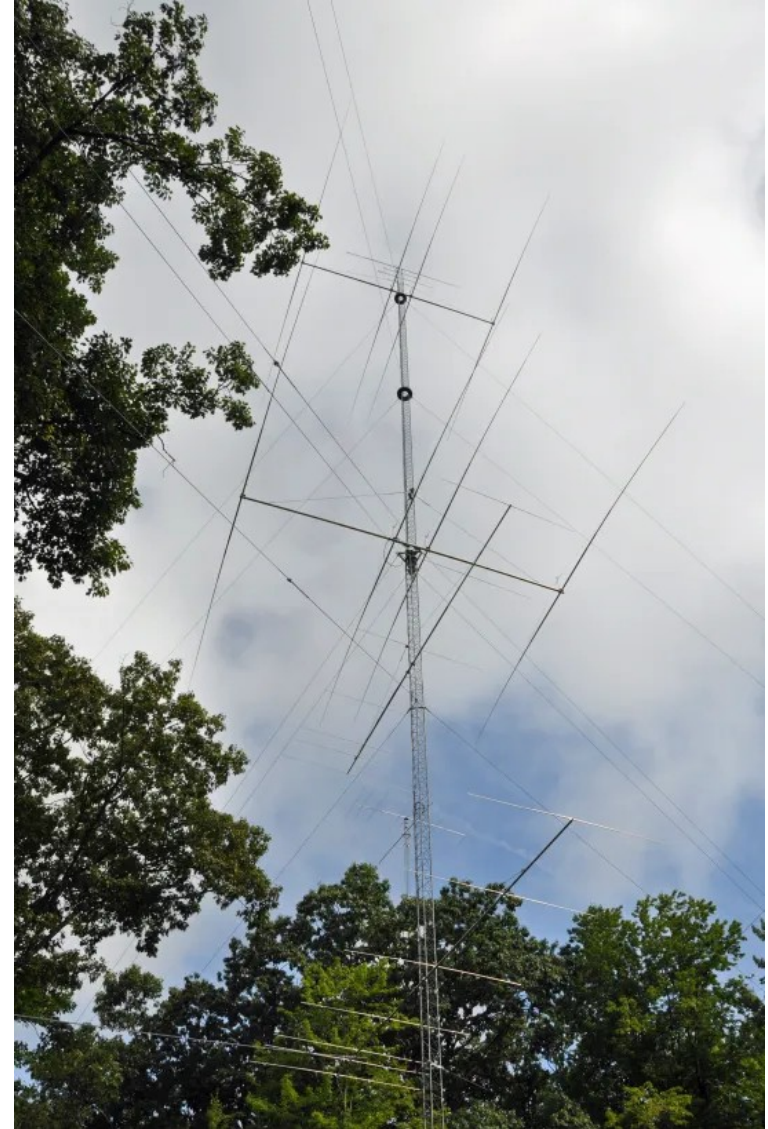
1. They Are both Compromise Antennas

# Three Things These Two Antenna Installations Have in Common



1. They Are both Compromise Antennas
2. They Were Both Designed with Specific Constraints in Mind

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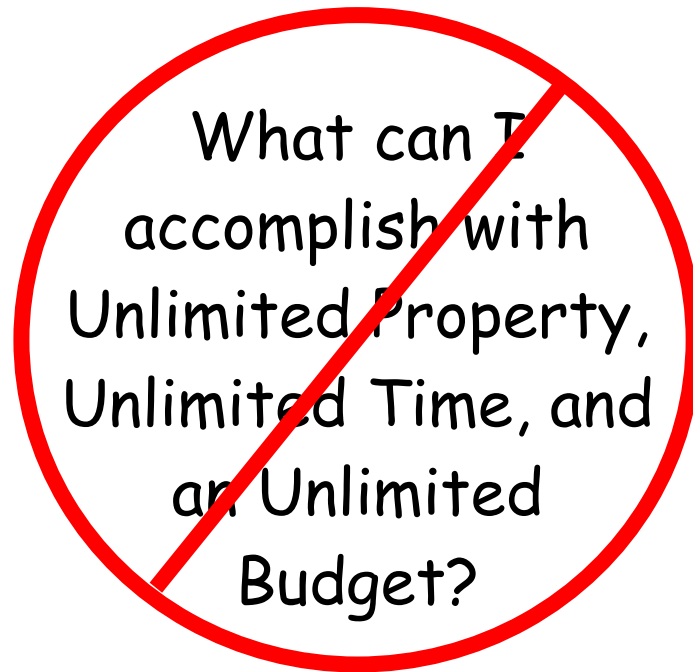


1. They Are both Compromise Antennas
2. They Were Both Designed with Specific Constraints in Mind
3. They Can Both Get You on HF

# Basic Practical Antennas

What can I  
accomplish with  
Unlimited Property,  
Unlimited Time, and  
an Unlimited  
Budget?

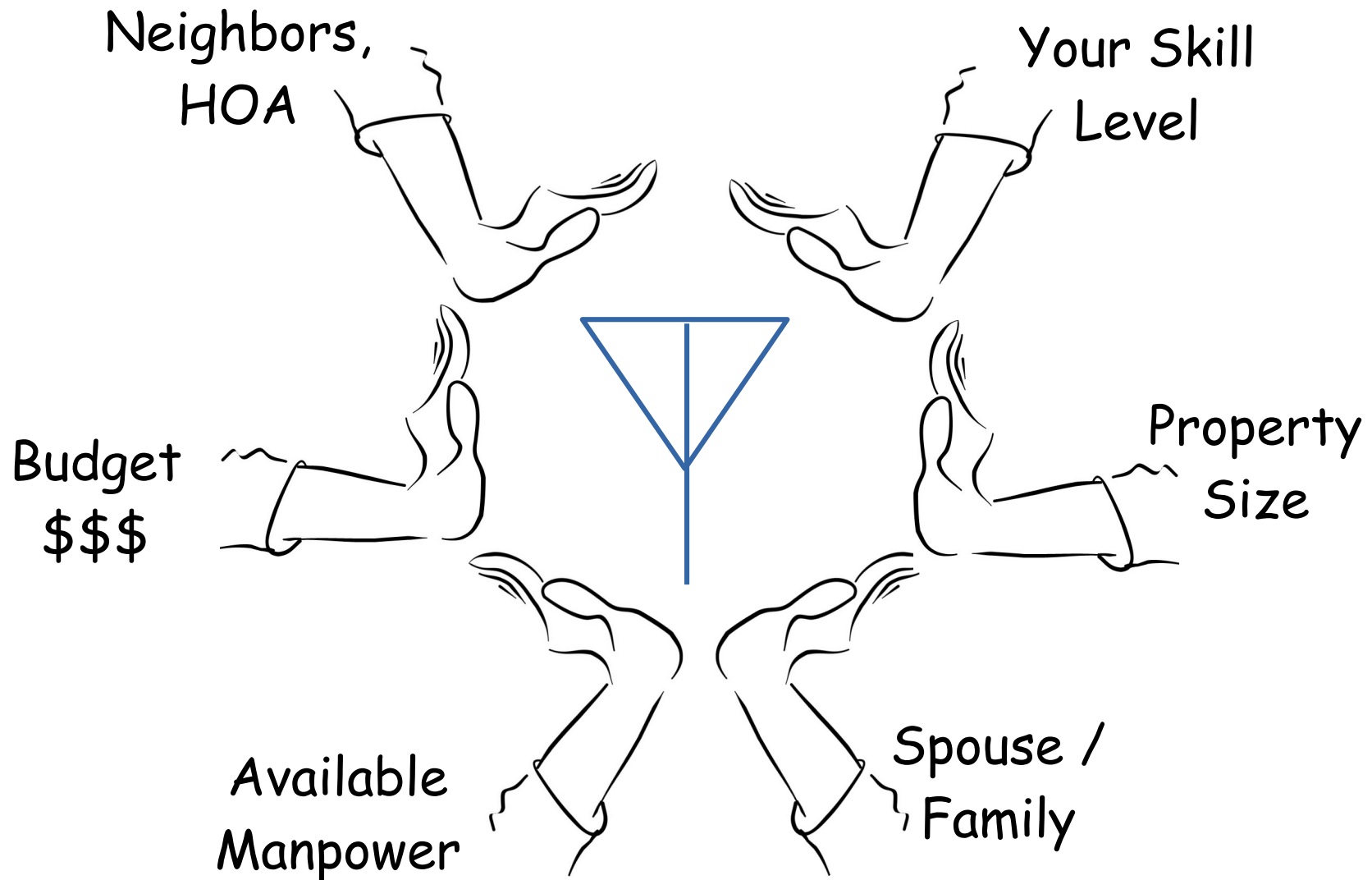
## Basic Practical Antennas



What can I accomplish  
with  
**What I've Got?**

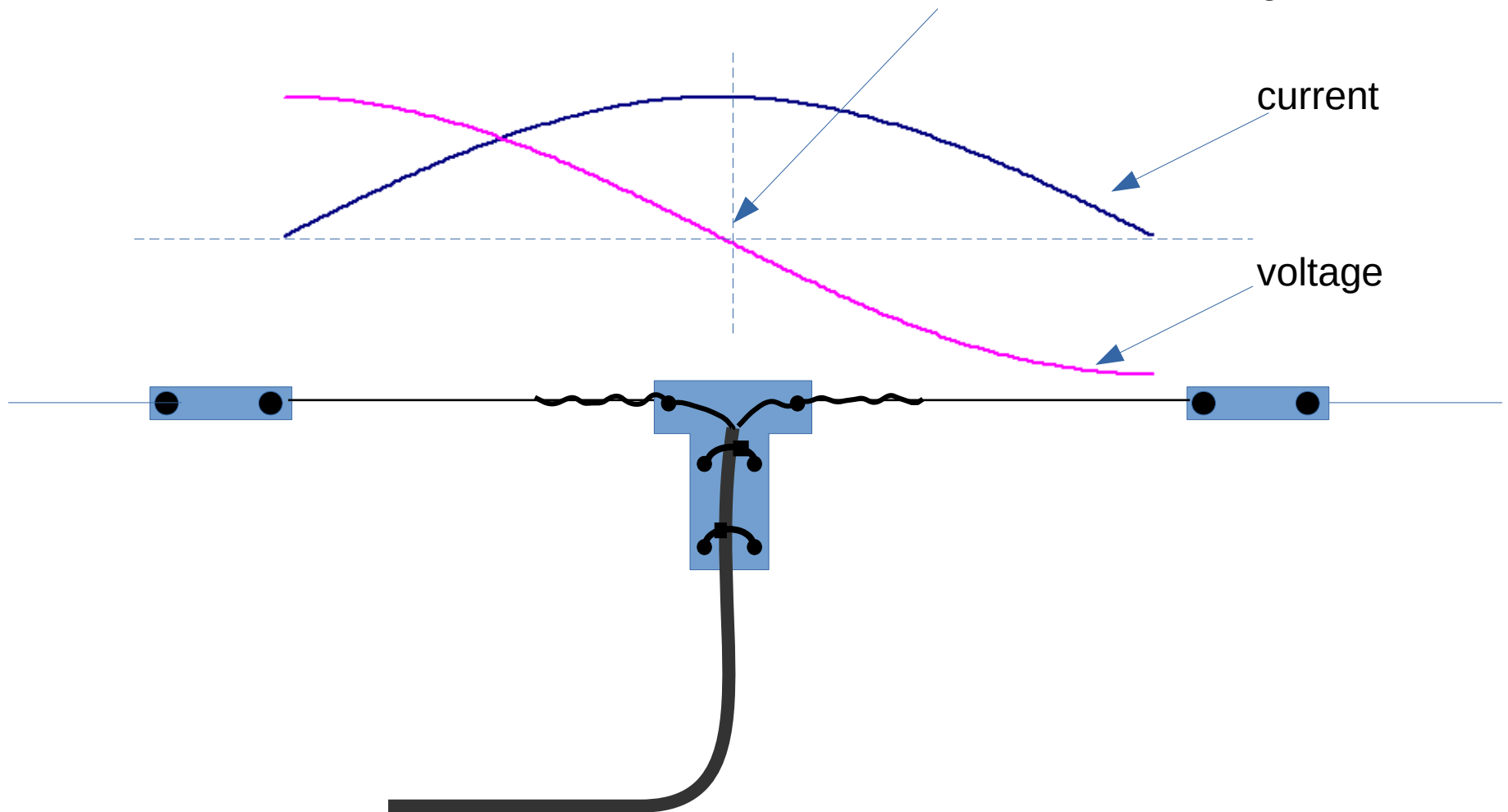
# Every Antenna is a Compromise Antenna !

## We All Have to Work Within **Constraints**



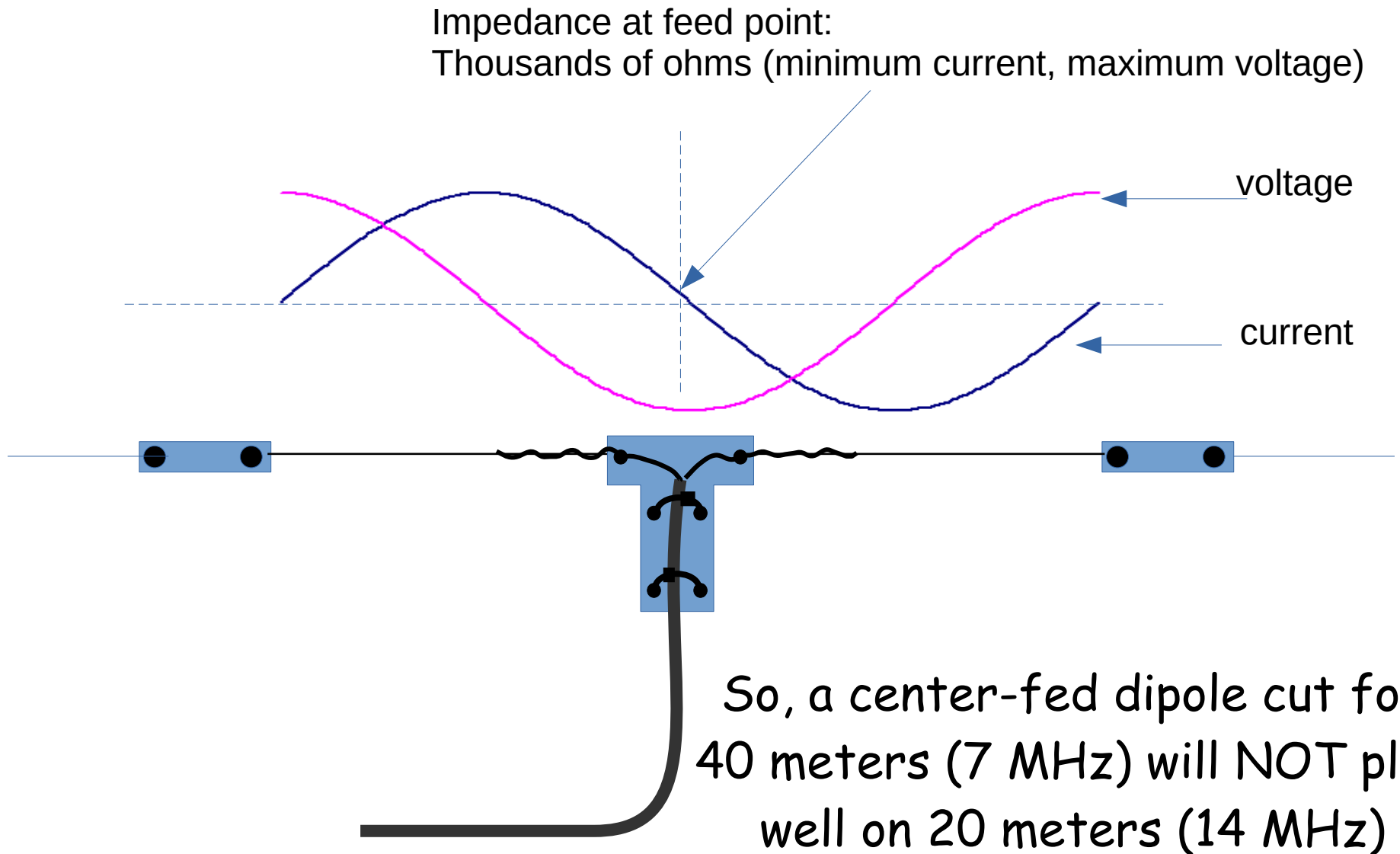
# Single-Band, Half-Wave, Center-Fed Dipole

Impedance at feed point:  
About 70 ohms in free space, but closer to 50  
ohms if the antenna is closer to the ground



# Single-Band, Half-Wave, Center-Fed Dipole

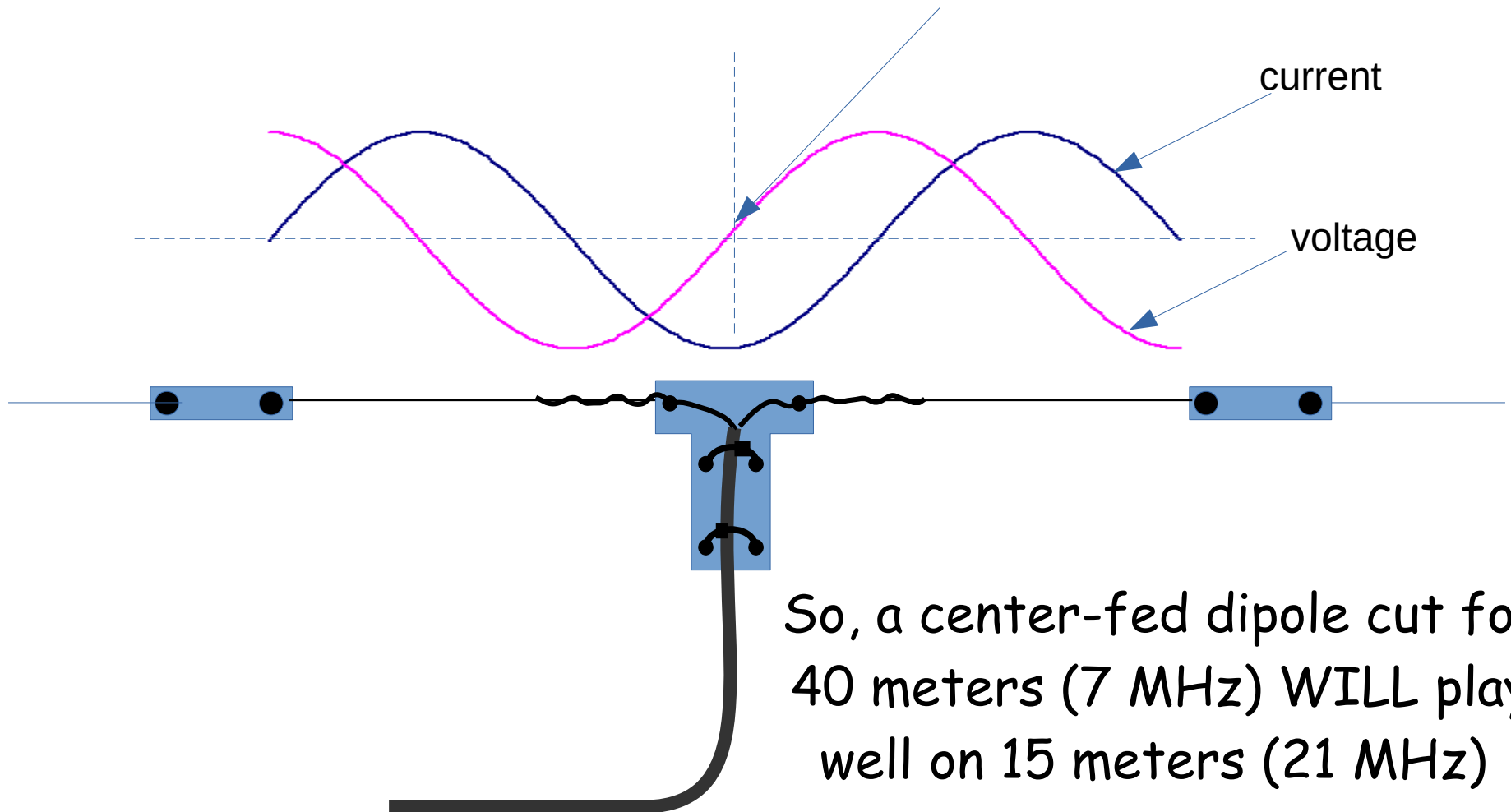
Not good for double the half-wave frequency



# Single-Band, Half-Wave, Center-Fed Dipole

## How about triple the half-wave frequency?

Impedance at feed point:  
Back to maximum current, minimum voltage!  
About 70 ohms in free space, but closer to 50 ohms if the antenna is closer to the ground

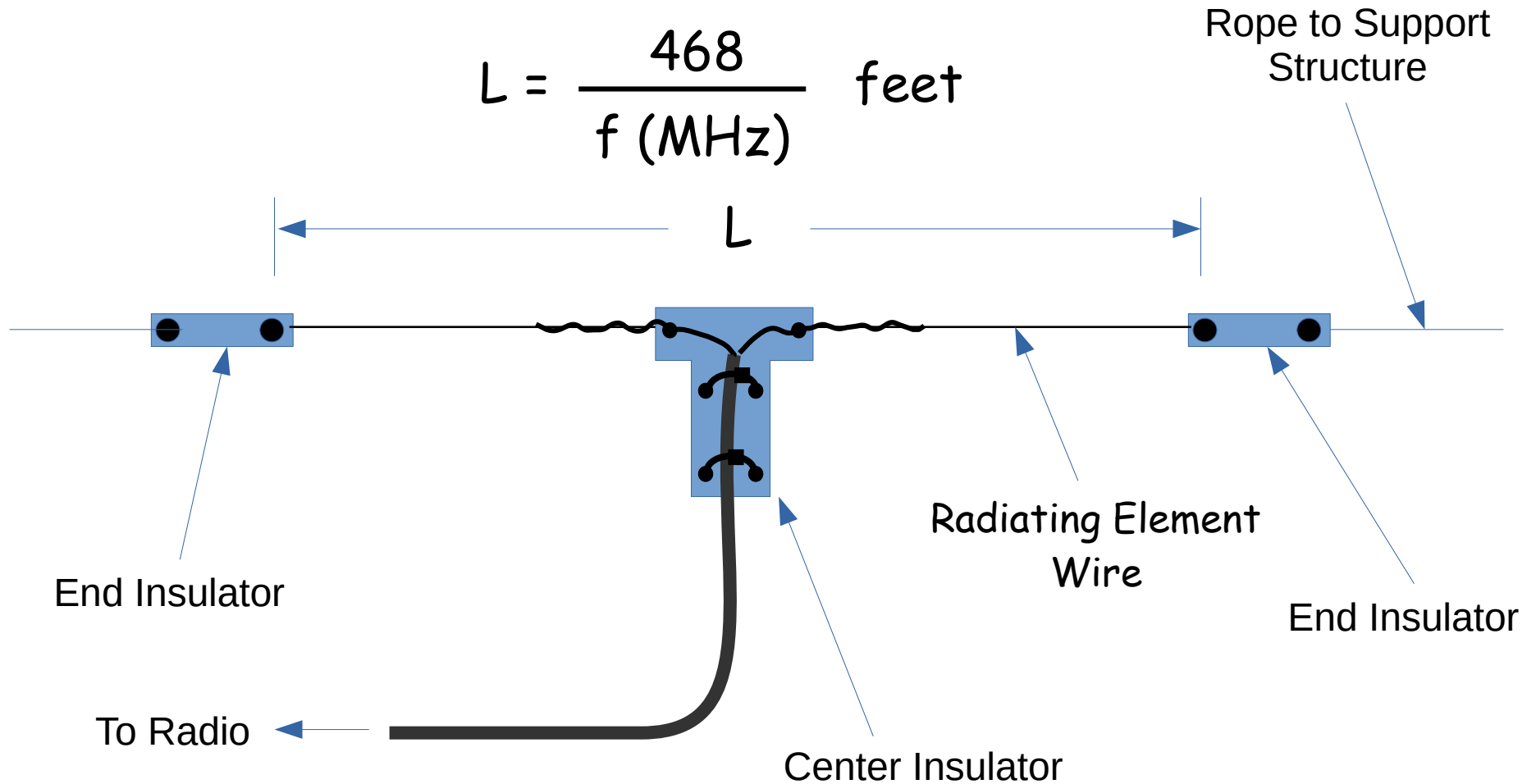


So, a center-fed dipole cut for  
40 meters (7 MHz) WILL play  
well on 15 meters (21 MHz)

Odd Harmonics GOOD, Even Harmonics BAD

# Single-Band, Half-Wave, Center-Fed Dipole

$$L = \frac{468}{f \text{ (MHz)}} \text{ feet}$$



## 1/2 Wave Dipole Lengths (Starting Point)

Band	Frequency	Length (feet)
80 CW / Digital	3.575	130.91
75 Phone	3.900	120.00
40 CW/Digital	7.075	66.15
40 Phone	7.240	64.64
30 (CW Only)	10.125	46.22
20 CW / Digital	14.075	33.25
20 Phone	14.250	32.84
17 CW / Digital / Phone	18.100	25.86
15 CW/Digital	21.075	22.21
15 Phone	21.300	21.97
12 CW / Digital / Phone	24.940	18.77
10 CW / Digital	28.075	16.67
10 Phone (SSB)	28.300	16.54
10 FM	28.600	16.36
6 meter Calling freq	50.120	9.34

## Let's Pick a Band!

80 is primarily a night time band. With some creativity most of us can shoe-horn a half-wave (130 ft) dipole onto an average  $\frac{1}{4}$  acre lot.

40 is good for local (500-800 miles) during the day, but goes long for DX at night. A full size dipole (65 feet) can usually fit in a  $\frac{1}{4}$  acre property.

20 is your meat and potatoes daytime DX band, starts to close at night except at the very top of the sunspot cycle. A full size dipole (33 feet) is relatively easy to get onto a  $\frac{1}{4}$  acre property.

15 thru 10 - fewer band openings, but their openings are much more intense than 20.

You've seen this formula for a half wave antenna...

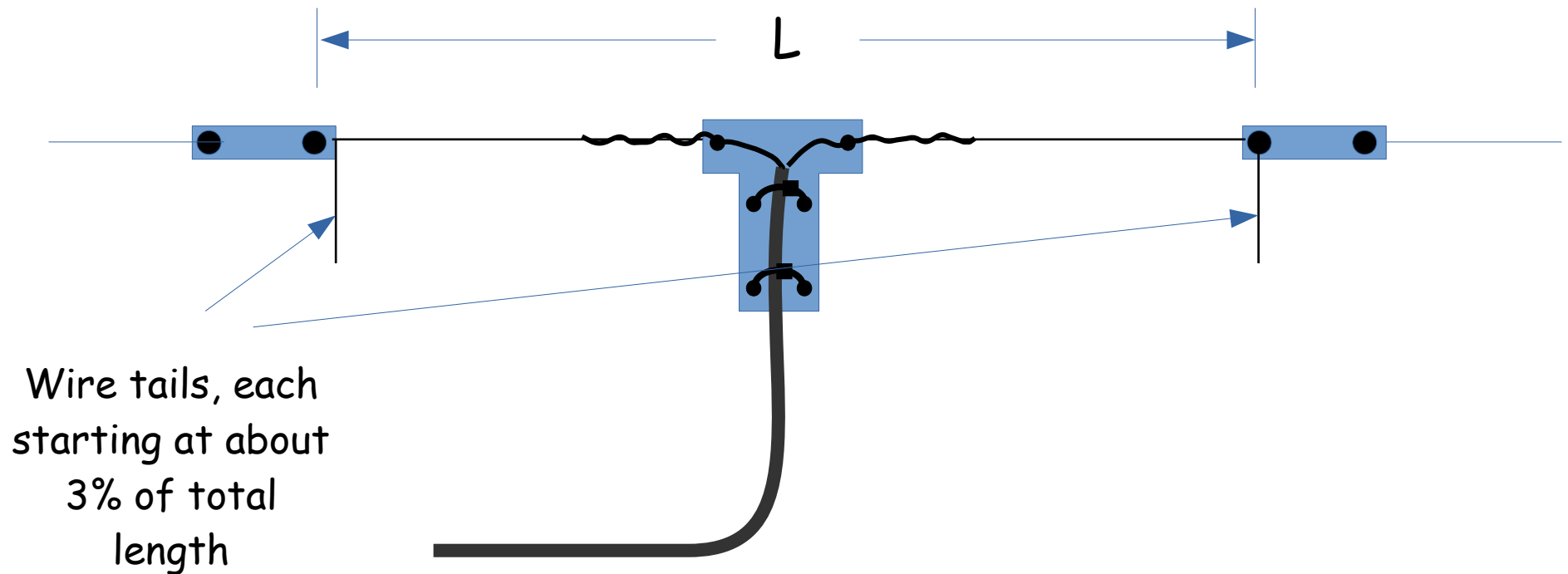
$$L = \frac{468}{f \text{ (MHz)}} \text{ feet}$$

So where do we get the 468??

- Radio Waves travel at the speed of light, about 300,000,000 meters/second
- This translates to 984,000,000 feet/second
- One wavelength of an RF wave is  $984,000,000/f$  (cycles/sec) or  $984/f(\text{MHz})$
- So  $\frac{1}{2}$  wave, in feet, is  $492/f(\text{MHz})$
- For various reasons - end effects, velocity factor of the wire, interaction with ground (physicists debate on the exact reason), antennas need to be about 5% shorter than  $492/f$ .
- $492 \times .95 = 467.4$  or approximately 468.
- This is a rule of thumb; it may (probably *will*) be different at your specific location!

## Here's what I like to do...

$$L = \frac{468}{f \text{ (MHz)}} \text{ feet} - 5\%$$



Initially, shoot for TOO LONG with the tails and TOO SHORT without the tails.

We'll trim the tails down based on actual antenna behavior.

# Tuning the Dipole

1. Find the actual frequency where your SWR is MINIMUM
2. If the actual frequency is LOWER than where you plan to operate, the antenna is TOO LONG; trim the tails by this amount:

$$\left(1 - \left(\frac{\text{Actual Freq}}{\text{Desired Freq}}\right)\right) \times \text{Original Length} \times 12 \text{ inches}$$

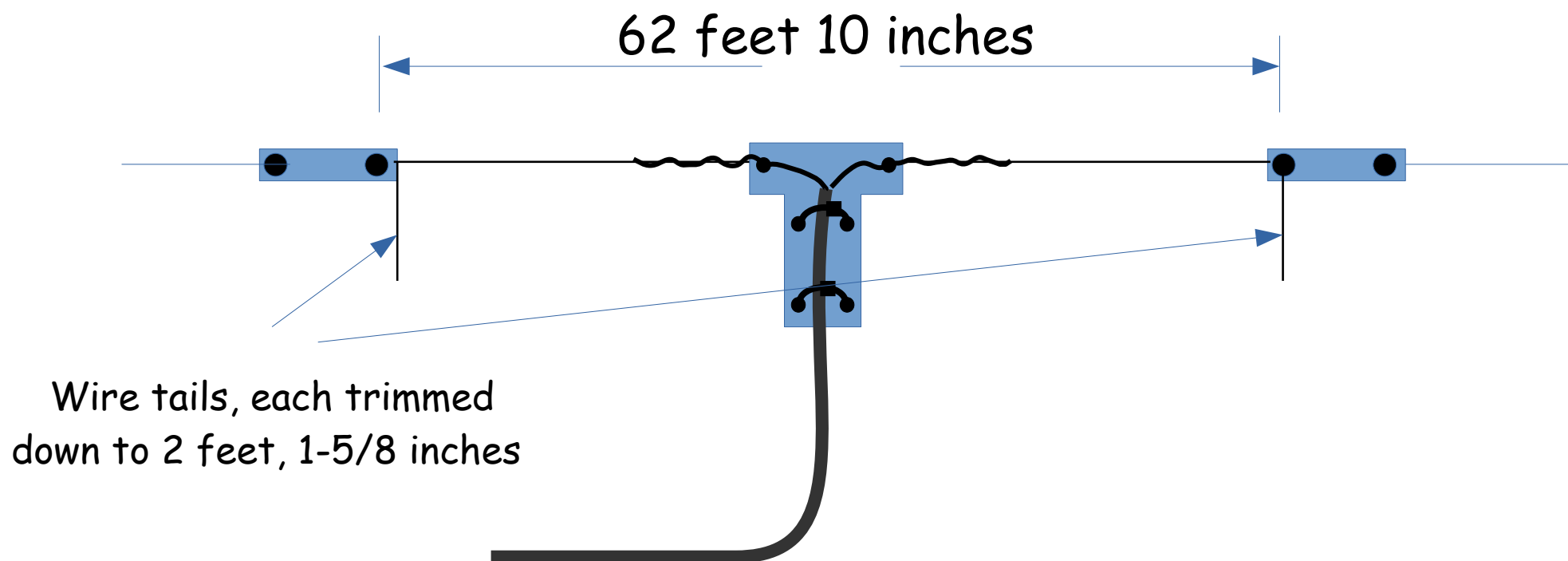
3. If the actual frequency is HIGHER than where you plan to operate, the antenna is TOO SHORT; lengthen the tails by this amount:

$$\left(1 - \left(\frac{\text{Desired Freq}}{\text{Actual Freq}}\right)\right) \times \text{Original Length} \times 12 \text{ inches}$$

# 40 Meter Dipole Example

- We want to build a dipole for 40 meters
- FT-8 is a popular mode and 40 meter FT-8 activity is at 7.074 MHz
- Our starting point is  $468 / 7.074 = 66.16$  feet, or about 66 ft 2 inches.
- That's 33 ft 1 inch per side.
- Let's make the main sides about 95% of that, or 31 feet 5 inches
- The tails are just about 2 feet. I'd rather start too long than too short because it's easier to cut the tails than lengthen them so let's go to 2 ft 6 inches. Original length of each side is 33 feet 11 inches or 33.92 feet.
- Haul the antenna up and measure the SWR above and below 7.074 MHz. If you have an antenna analyzer you can make measurements below 7 MHz. Look for the frequency with the lowest SWR.
- Suppose the best frequency is 6.998 MHz. As planned, the antenna is too long and it's time to trim the tails down.
- $(1 - 6.998 / 7.074) * 33.92 * 12 = 4.37$  inches (about 4-3/8 inches)
- So trimming the tails by 4-3/8 inches from each tail should get us to 7.074 MHz.
- You'll do OK in the CW band and most of the phone band with this antenna.

So here's what we ended up with . . .



This antenna is optimized for the 40 meter FT-8 sub-band but should be OK for all of CW band and most of SSB on 40 meters.

# Some Insulator Options for Wire Antennas

Homebrew Insulators are Easy...

Just be sure to use non-porous materials!

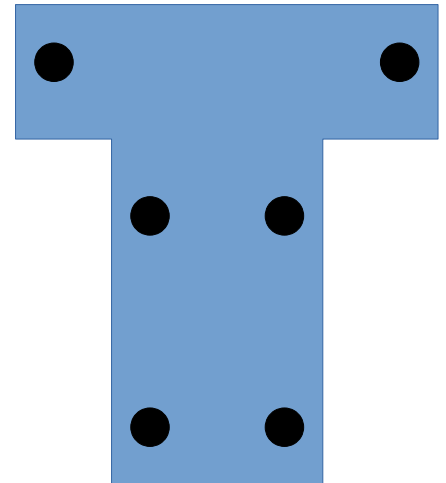
Inexpensive Store Bought  
Insulators



Dog Bone Insulator



Homebrew Lexan Insulator



Quick Center Insulator Idea  
Top two holes drilled for wire  
Bottom four holes are for  
tie-wraps to secure feed line



Egg Insulator



Drill a couple of holes in a  
piece of PVC pipe!

# Flat Top - If you have two support structures (Trees in this case)

Height Above Ground

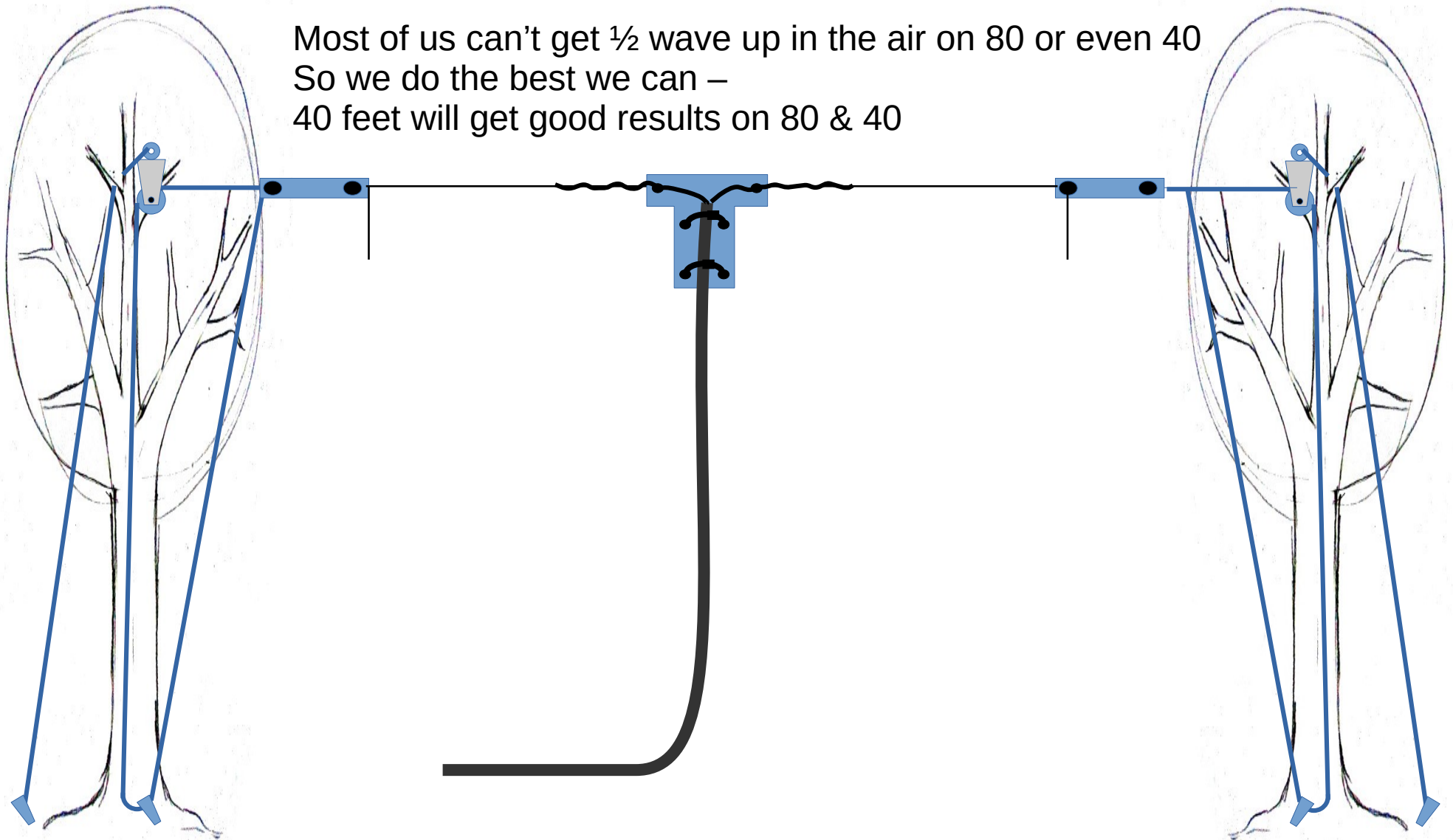
Ideally, minimum  $\frac{1}{2}$  wave above the ground

80m: 130 ft, 40m: 66 ft, 20m: 33 ft

Most of us can't get  $\frac{1}{2}$  wave up in the air on 80 or even 40

So we do the best we can –

40 feet will get good results on 80 & 40



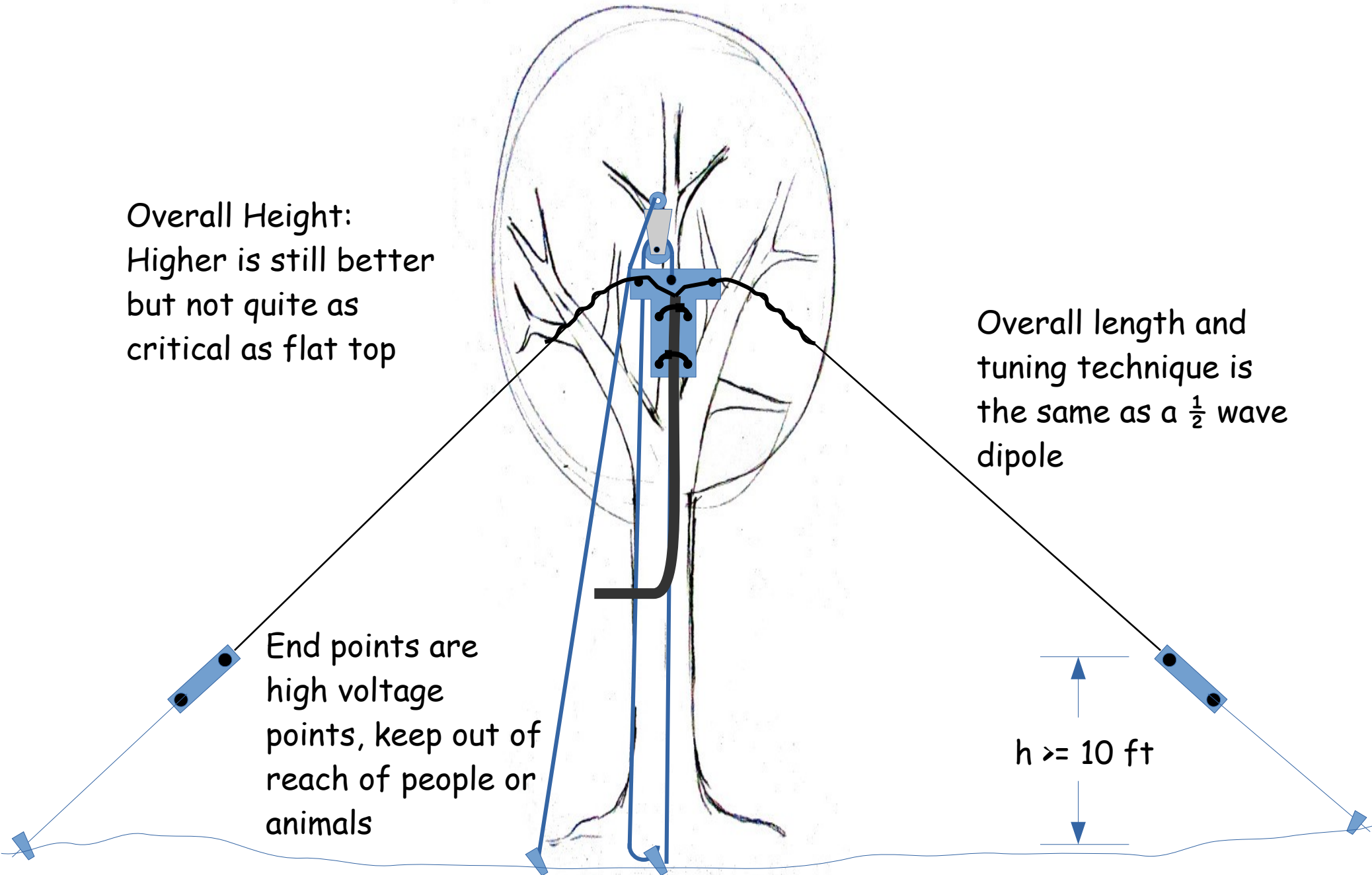
# Only one support available? Consider an Inverted VEE

Overall Height:  
Higher is still better  
but not quite as  
critical as flat top

Overall length and  
tuning technique is  
the same as a  $\frac{1}{2}$  wave  
dipole

End points are  
high voltage  
points, keep out of  
reach of people or  
animals

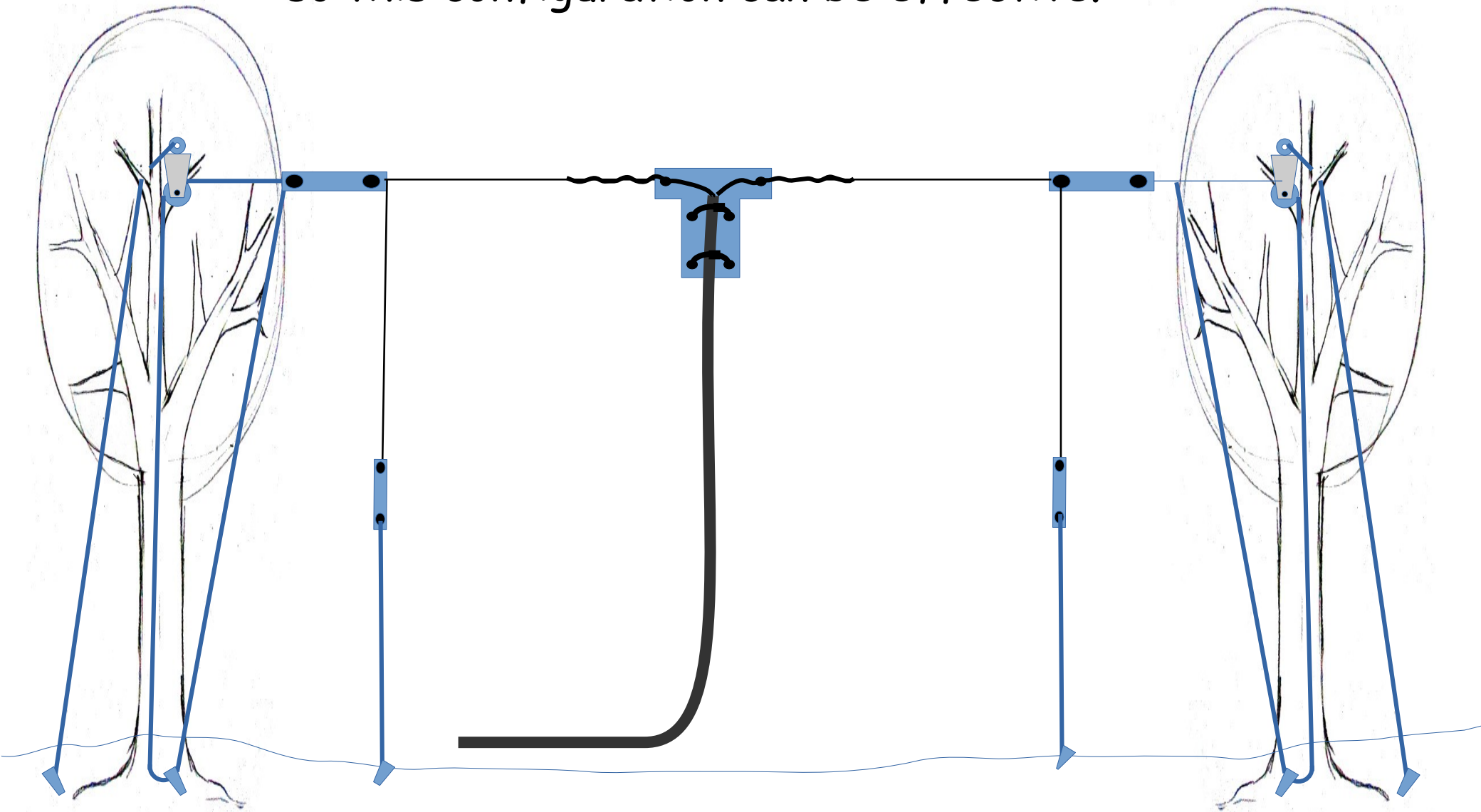
$h \geq 10 \text{ ft}$



Got 2 trees but not far enough apart for a  $\frac{1}{2}$  wave antenna?

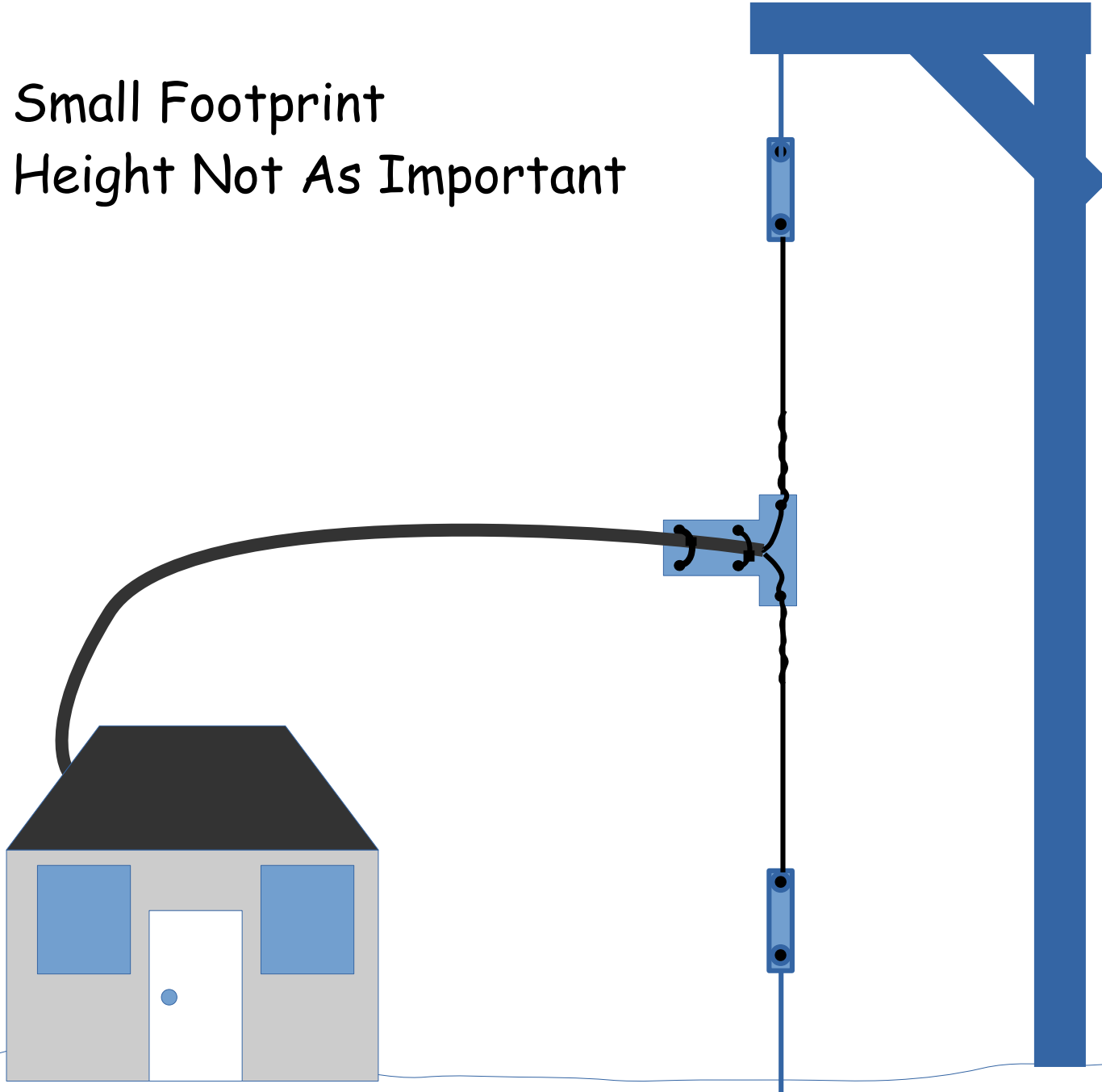
You can bend your dipole into an Inverted U.

The middle 60% of the antenna does most of the work,  
so this configuration can be effective.



# Vertical Antennas

- Small Footprint
- Height Not As Important



- Half Wave Verticals Work on Same Principle as a Dipole
- Low Takeoff Angle, Good for DX

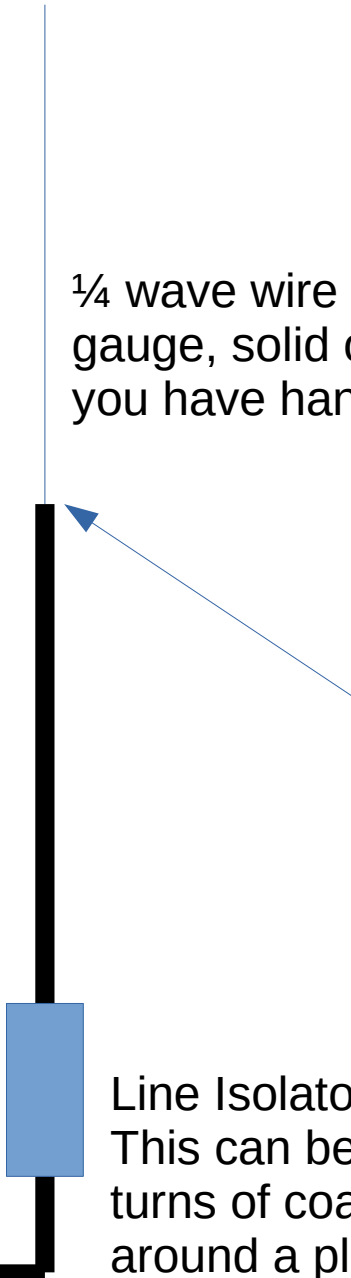
# Here's a More Practical Approach to Homebrewing a Half Wave Vertical

$\frac{1}{4}$  wave wire (22 gauge to 14 gauge, solid or stranded - whatever you have handy)

## Feed Point

- Trim shield of coax back so it doesn't short to the center conductor
- Solder the center conductor of the coax to the top section
- Cover with electrical tape or shrink wrap.

Line Isolator -  
This can be as simple as 10 turns of coax wound into a coil around a plastic coke bottle



## 1/2 Wave Coaxial Vertical Lengths (Starting Point)

Frequency	Lower Element	Upper Element	Total Height
3.750	58' 9"	62' 3"	121' 0"
7.150	30' 6"	32' 6"	63' 0"
10.125	21' 5"	22' 1"	43' 6"
14.175	15' 2"	16' 4"	31' 6"
18.118	11' 10"	12' 10"	24' 8"
21.225	10' 1"	11' 0"	21' 1"
24.950	8' 7"	9' 4"	17' 11"
28.300	7' 6"	8' 3"	15' 9"

Coax Verticals are Great Portable Antennas for 14 Mhz and Up. Hang it From a Tree or a Fiberglass Push-Up Pole and You're On HF!

Not so practical on 40 and 80 meters - If you have a 63' or 121' vertical support you will do better with an inverted Vee.

# Helically-Wound Vertical: You can get on 160 meters!

*Designed by  
John Miller, K6MM*

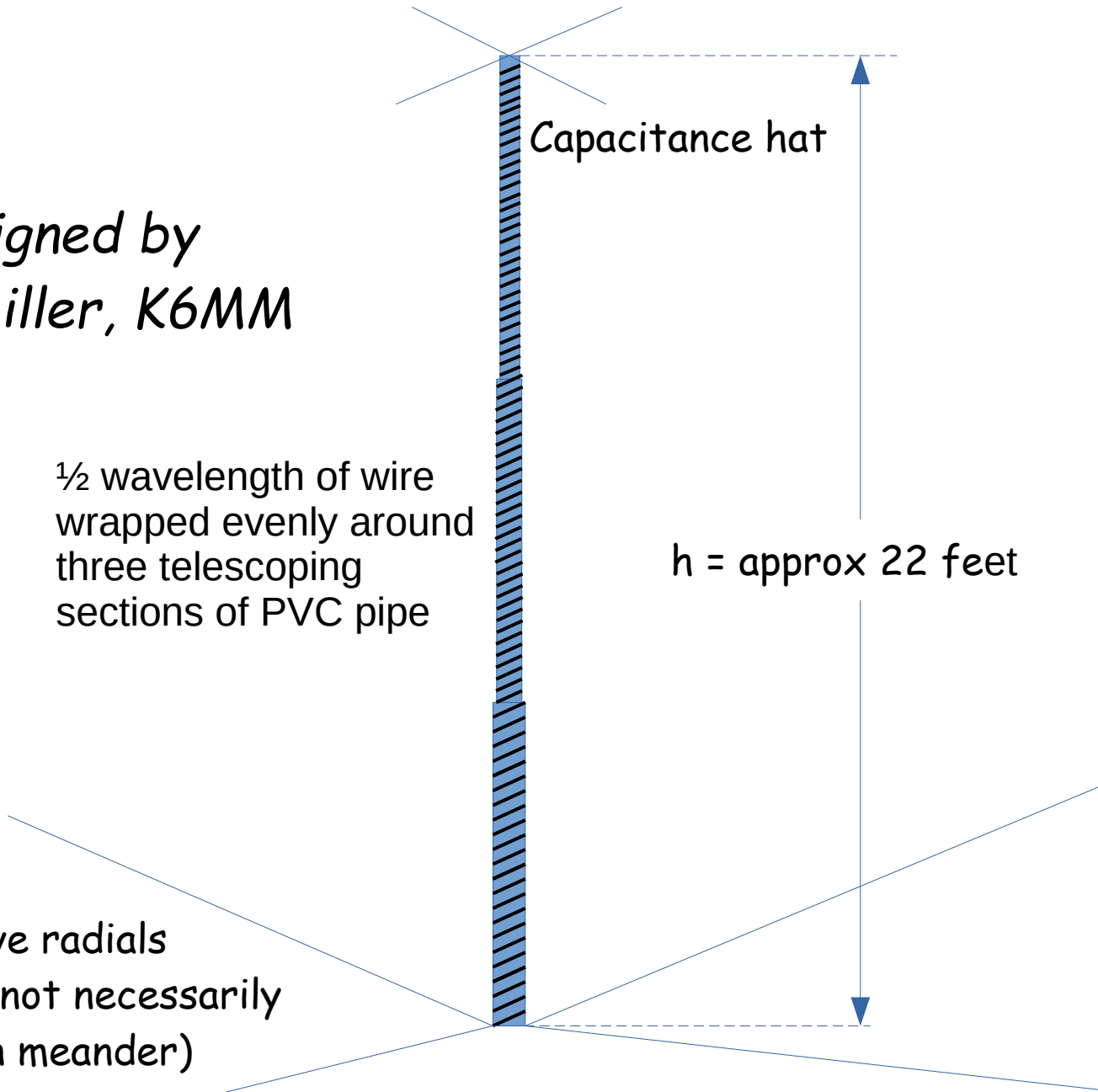
$\frac{1}{2}$  wavelength of wire  
wrapped evenly around  
three telescoping  
sections of PVC pipe

Capacitance hat

$h = \text{approx } 22 \text{ feet}$

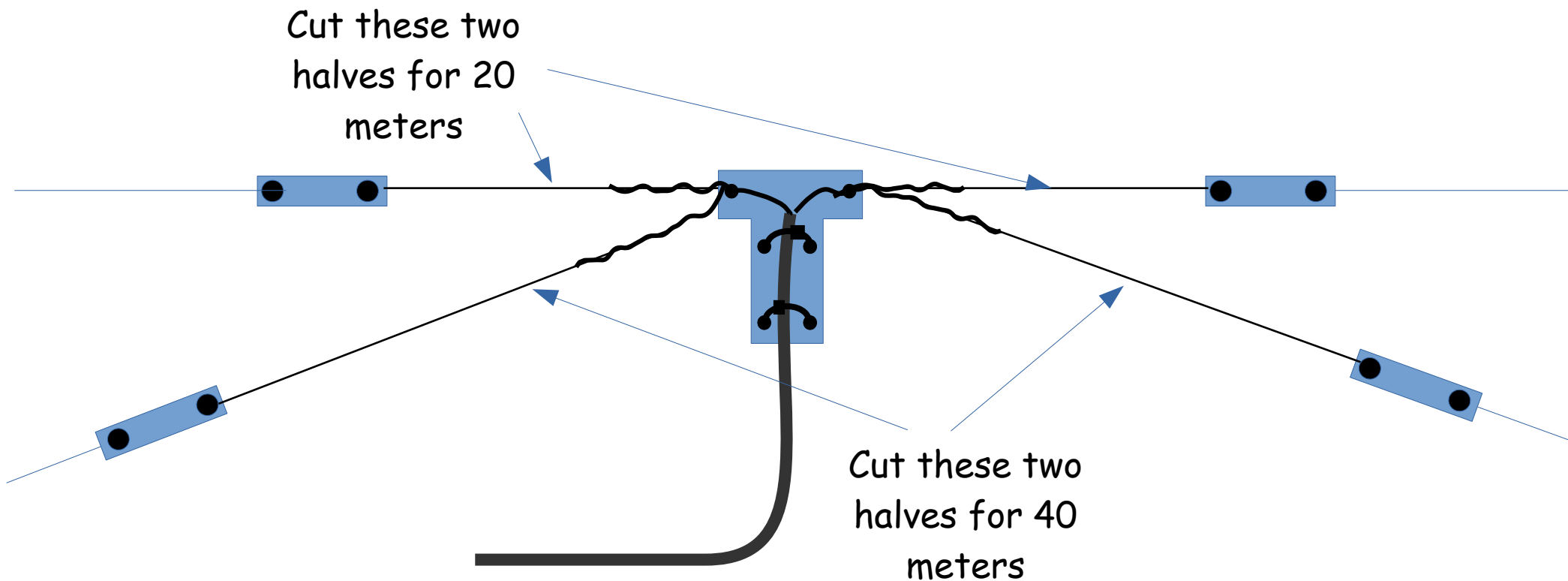
Quarter-wave radials  
(4 minimum, not necessarily  
straight, can meander)

Construction details at <http://www.smeter.net/antennas/short-helical.php>



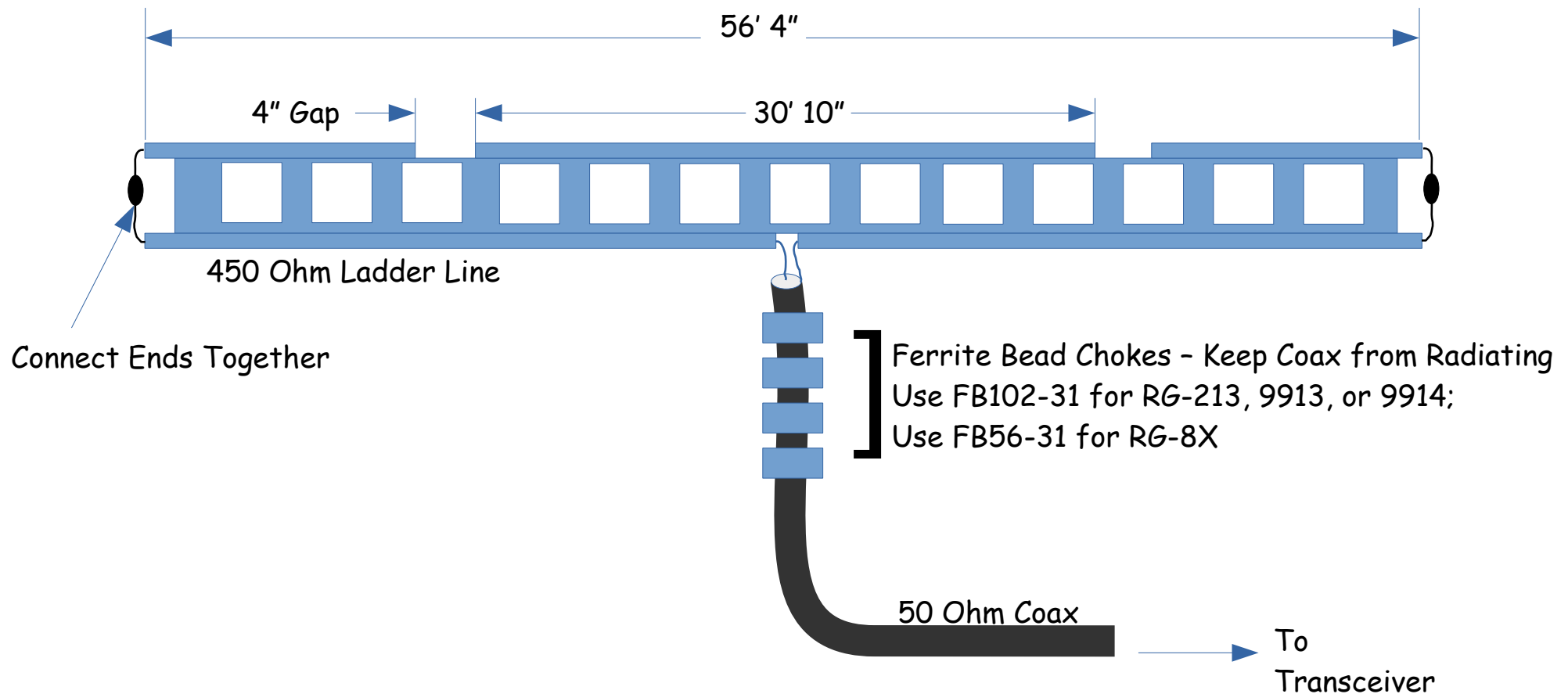
# Multi-Band Antennas

# A Multi-Band Fan Dipole for 40, 20, and 15 meters



- On 20 meters, the 40 meter dipole is high impedance at the center so the practically all of the power goes into the 20 meter dipole.
- Similarly, on 40 meters, the 20 meter dipole is a higher impedance than the 40 meter section, so the power goes to the 40 meter dipole.
- As an added bonus, the 40 meter side will do OK on 15 as well! (odd harmonic)

# W1ZR Dual Band Folded Skeleton Sleeve Dipole



- Adjust the 40 meter section first, then the 20 meter section.
- Interaction between 40 meter element and 20 meter element is minimal if at all.
- As an added bonus, the 40 meter section will do OK on 15 as well! (odd harmonic)

# G5RV Multi-Band Dipole

## Variations:

- Lengthen ladder line to 36' for a no-tuner 50 ohm match on 40 meters
- Cut all dimensions in half to get a "G5RV Junior", good on 40 and 20 but not so good on 80 meters
- Double the dimensions for a 160/80/40 meter antenna

- Originally Designed for 20 Meters
- Works Best as Flat Top
- Higher is Better (at least 31 feet)
- Good on 80, 40, and 20 with tuner
- Can be tuned on other bands with tuner, but not as effective

50  $\Omega$  Resistive @ 7.8 MHz  
at transition to coax cable

Weatherproof this transition  
from ladder line to coax

Ferrite Bead Chokes - Keep Coax from Radiating  
Use FB102-31 for RG-213, 9913, or 9914;  
Use FB56-31 for RG-8X

50 Ohm Coax

Antenna Tuner



To  
Transceiver

# Random Length Doublet ("Zepp")

Any Length, preferably at  
least  $\frac{1}{2}$  wave on lowest band

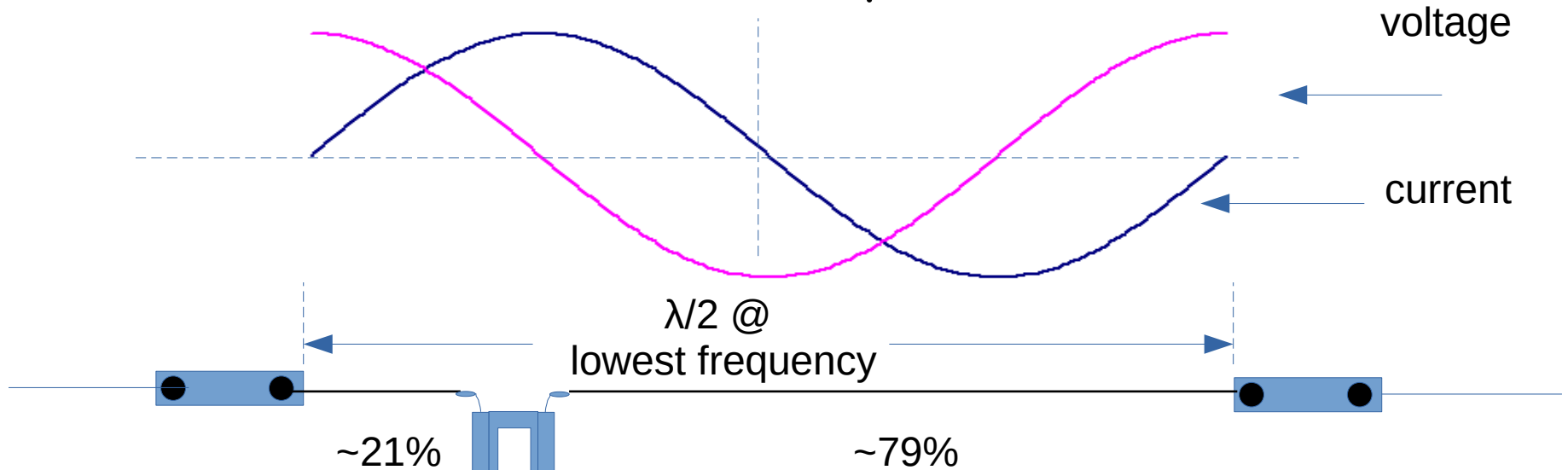
Any Length  
450 ohm ladder line or  
open wire feeder



To  
Transceiver

Balanced Wire Antenna Tuner  
(Most commercially made tuners can handle this)

# Off-Center Fed Dipole (OCFD)



Most bands will require a good external tuner

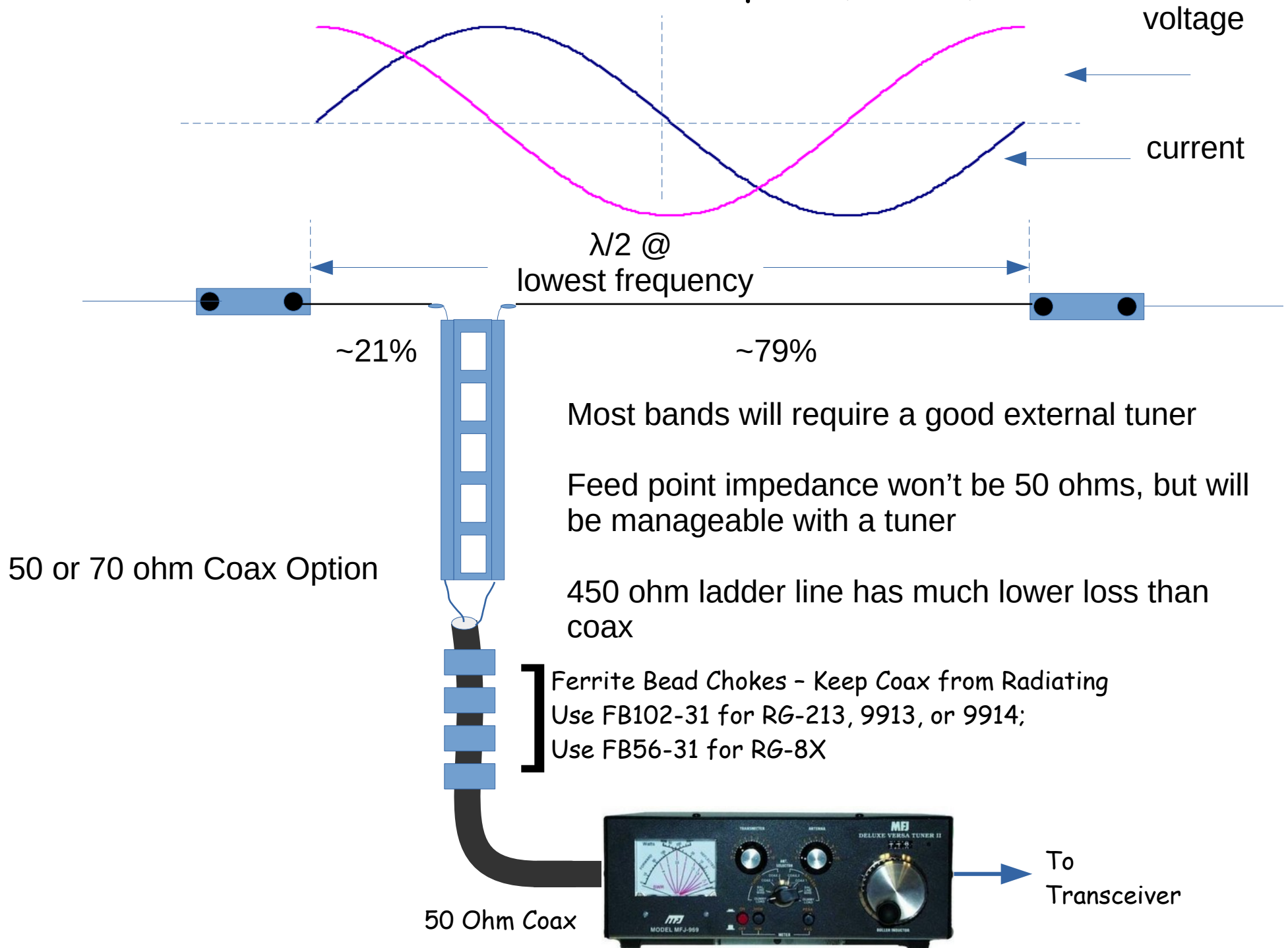
Feed point impedance won't be 50 ohms, but will be manageable with a tuner

450 ohm ladder line has much lower loss than coax

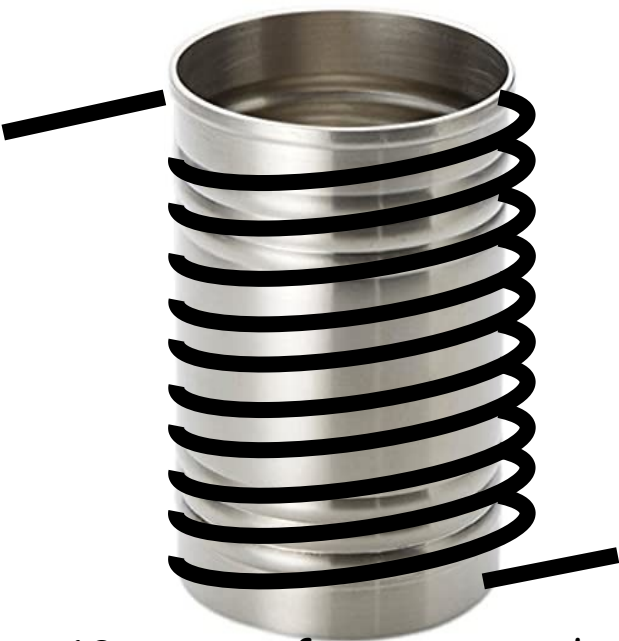


To  
Transceiver

# Off-Center Fed Dipole (OCFD)



# Keeping RF In the Coax Cable and Off of the Shield



~ 10 turns of coax wound  
around an old coffee can



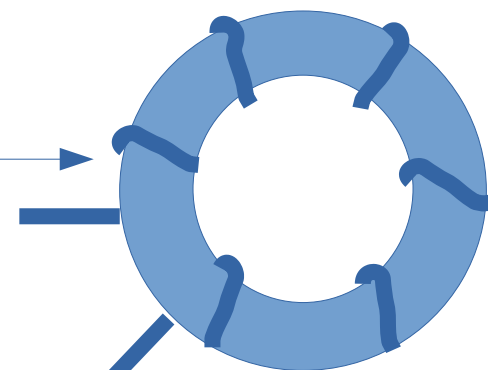
Store Bought "Line Isolator"  
These retail for about \$60.00

Ferrite Compositions:

Mix 31 good down to 1 MHz  
Mix 43 good above 10 MHz



Mix 31 Ferrite Beads  
Slipped Over the Coax



5 or 6 turns Through a  
Mix 31 Ferrite Core

# Antenna Getter Uppers



EZ-Hang  
(Check local laws!)



Light Fishing Rod and Golf Ball

33 ft telescoping  
fiberglass mast



Magic Rock and String



Pneumatic Launcher

Recommended Reading . . .

A Comparative Look at Multiband Antennas

<http://www.hamclass.net/rarv/pres/HC16MultAnt.pdf>

Joel R. Hallas, W1ZR

<https://www.hamuniverse.com/k6mm160metervertical.html>

The "No-Excuses" 160 Meter Vertical

(As published in the June 2009 issue of QST)

John Miller, K6MM

ARRL's

# Small Antennas for Small Spaces

Projects and Advice for Limited-Space Stations



Steve Ford, W1WJY



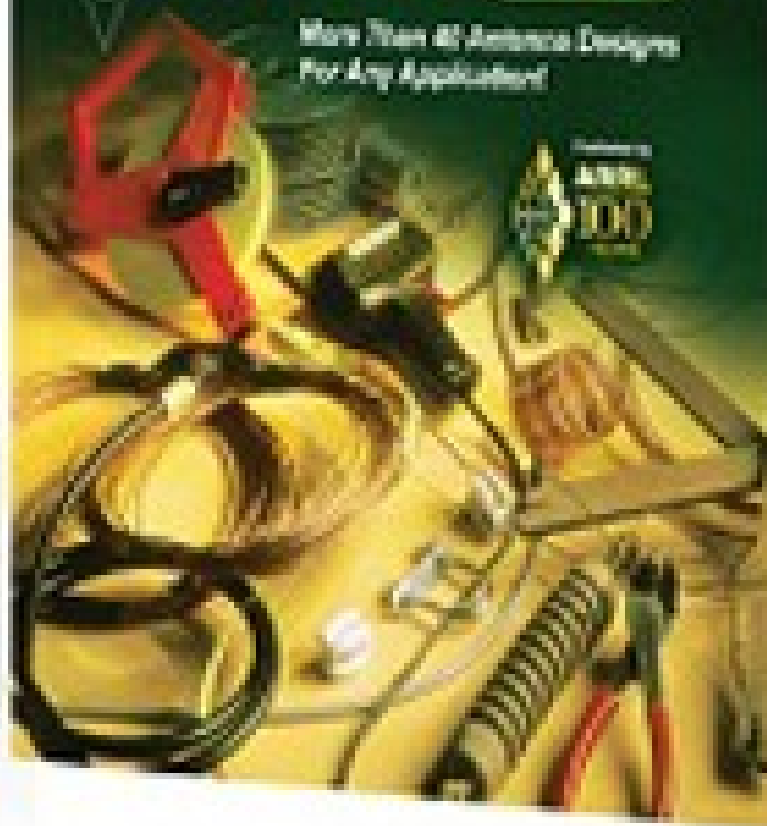
ARRL's

# Even More Wire Antenna Classics

Volume 3

More Than 80 Antenna Designs  
For Any Application!

Featuring  
ARRL  
100

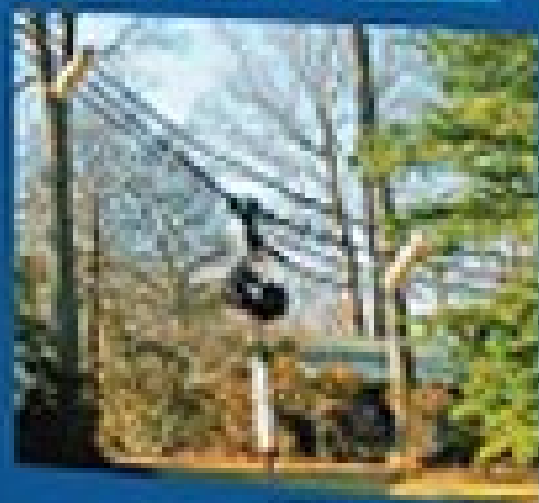




# HF Dipole Antennas for Amateur Radio

## 20 Innovative Antenna Projects!

Includes a special bonus section:  
20 Great Antenna Plans and Projects  
by William H. Orr, W1WJ

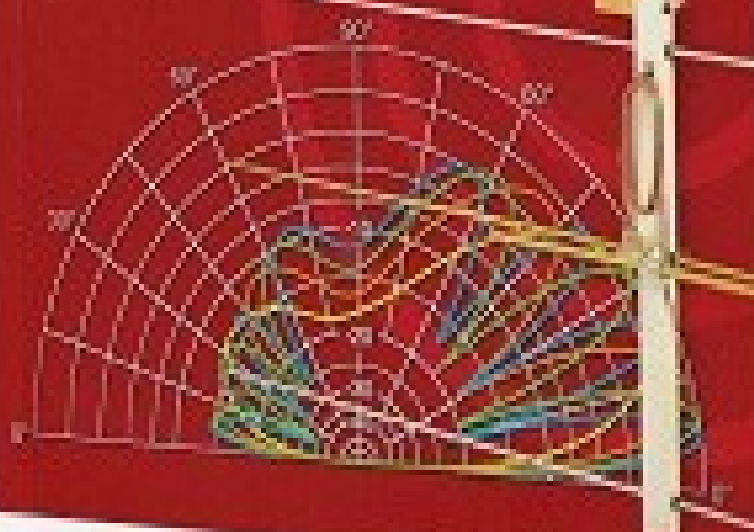


ARRL ANTENNA

THE ARRL  
**ANTENNA  
BOOK** 24th EDITION  
FOR RADIO COMMUNICATIONS



**ARRL** AMERICAN  
RADIO RELAY  
LIG



Thanks for Listening, 73, and See You On the Air!

Neil, KC2KY  
kc2ky@arrl.net

These Slides are Available at <http://www.rcarc.org/Presentations.htm>