

Wire Antennas For Limited Space

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Our Objectives

- **Good Antennas**
 - Good efficiency
 - Good predictable patterns
 - Minimal noise pickup and RFI
- **Inexpensive to build**
 - Wire
 - Insulators
 - Basic mechanical parts
 - Coax to feed them
 - Coax choke at feedpoint (for noise immunity)

Some Possibilities

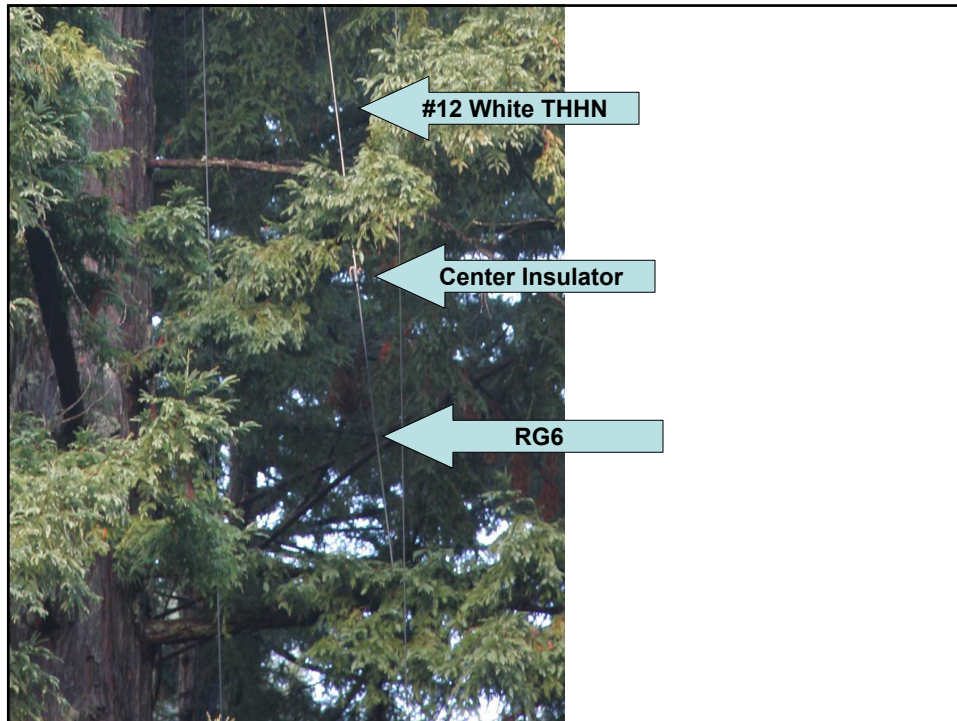
- **Half-wave dipoles**
 - Loading coils to make them shorter
 - Traps provide loading, fit multiple bands in same space
 - Fan dipoles fit multiple bands in same space
 - Sloping dipoles (some of the length is vertical)
 - Inverted Vee (some of the length vertical)
- **Top-loaded verticals**
 - Inverted L
 - Inverted Tee
- **End-fed wires**

How About A Vertical?

- A “good” vertical can beat a low dipole
- Low means less than about 0.3λ
 - 40 ft on 40M
 - 80 ft on 80M
 - 160 ft on 160M
- “Good” means efficient
 - Good radial system
 - Low losses (full size or top loading)
 - In the clear
 - Most commercial verticals are increasingly lossy below 30M

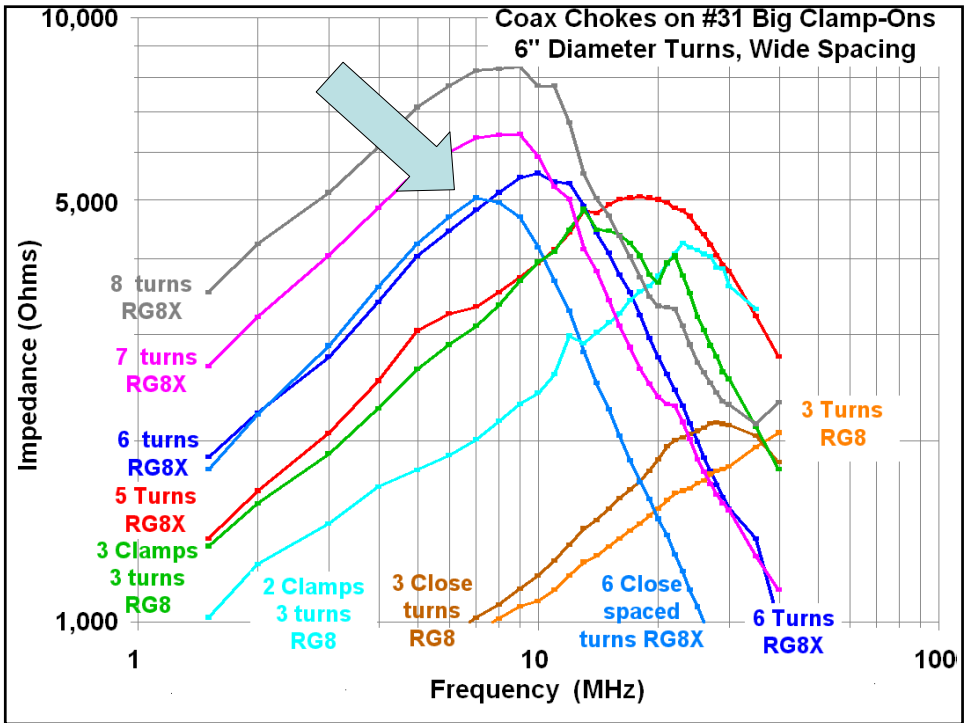
A Very Efficient 40M Vertical Dipole





End Insulator for a 40M Dipole

- **6 turns of RG6 around a “big clamp-on” is enough for 500 watts of serious contesting**
 - About 5,000 Ω resistive impedance
- **Two of these 6-turn chokes are needed for 1.5kW**
 - About 10,000 Ω resistive impedance



Before you fall in love with a vertical dipole, compare it to a horizontal dipole!

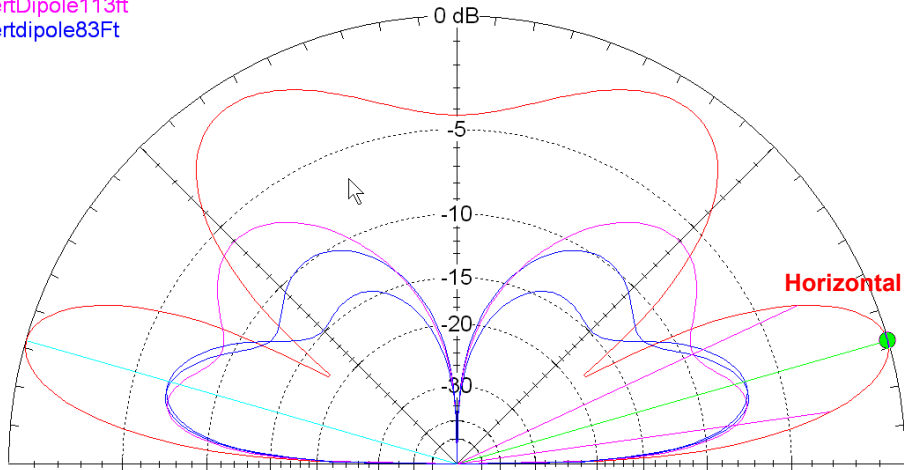
* Primary

VertDipole93Ft

VertDipole113ft

Vertdipole83Ft

Broadside to Horizontal Dipole



Before you fall in love with a vertical dipole, compare it to a horizontal dipole!

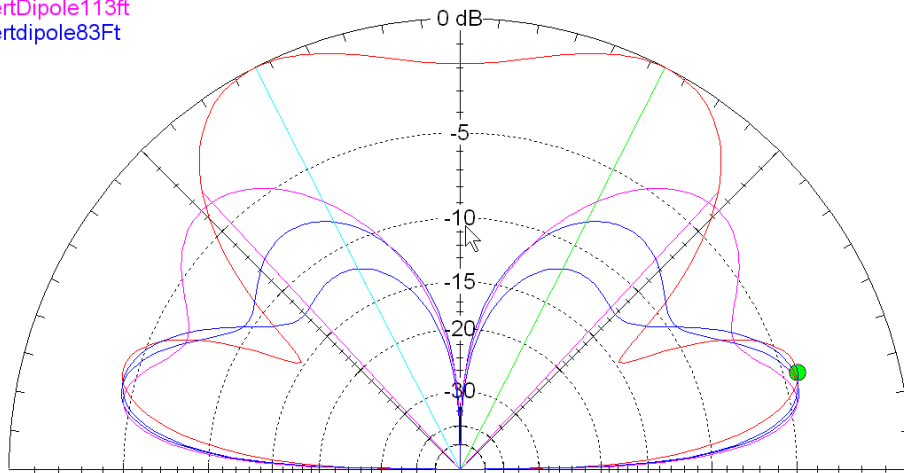
* Primary

VertDipole93Ft

VertDipole113ft

Vertdipole83Ft

60 Degrees off-axis of Horizontal Dipole

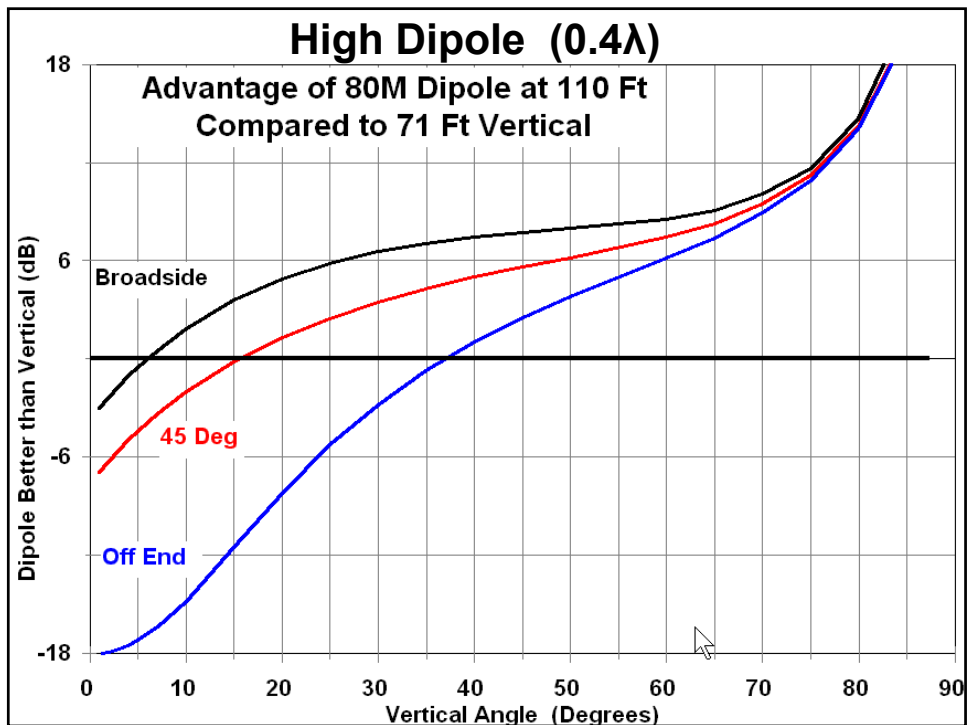
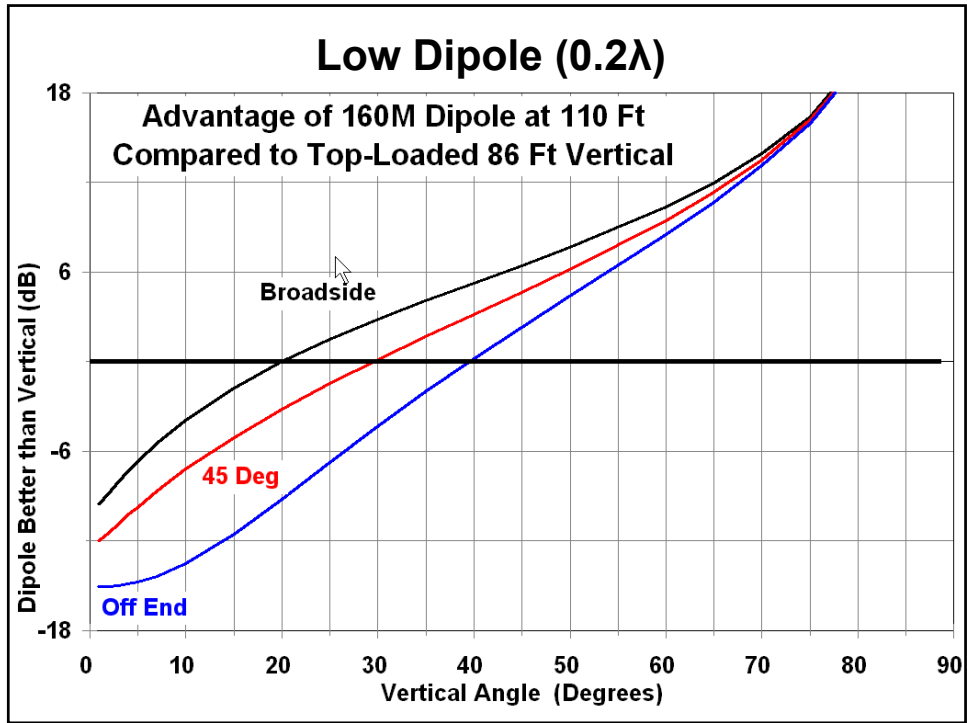


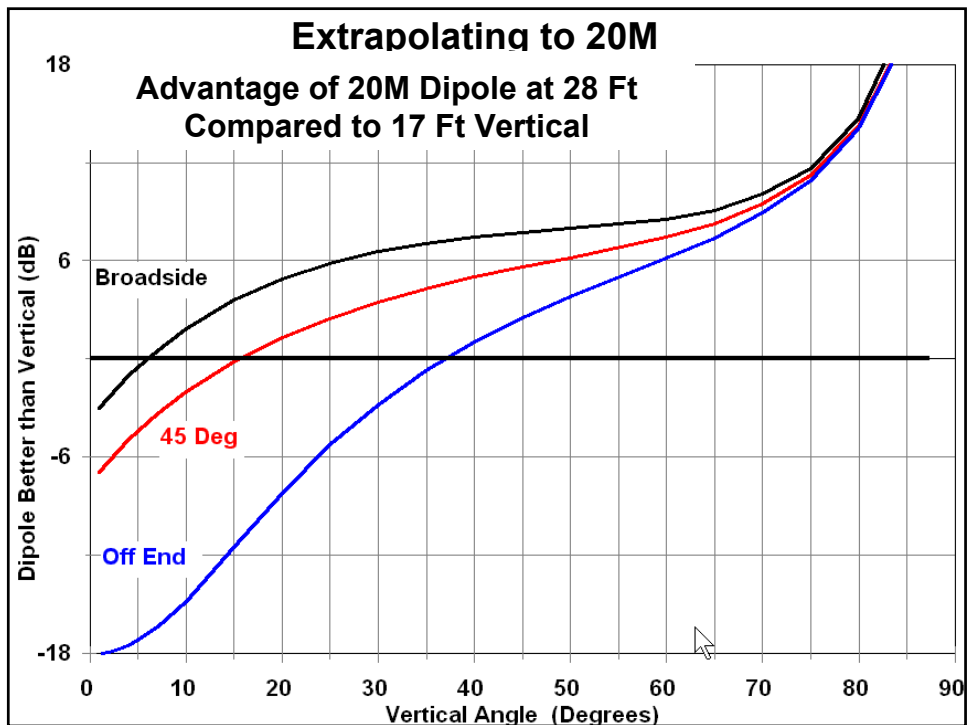
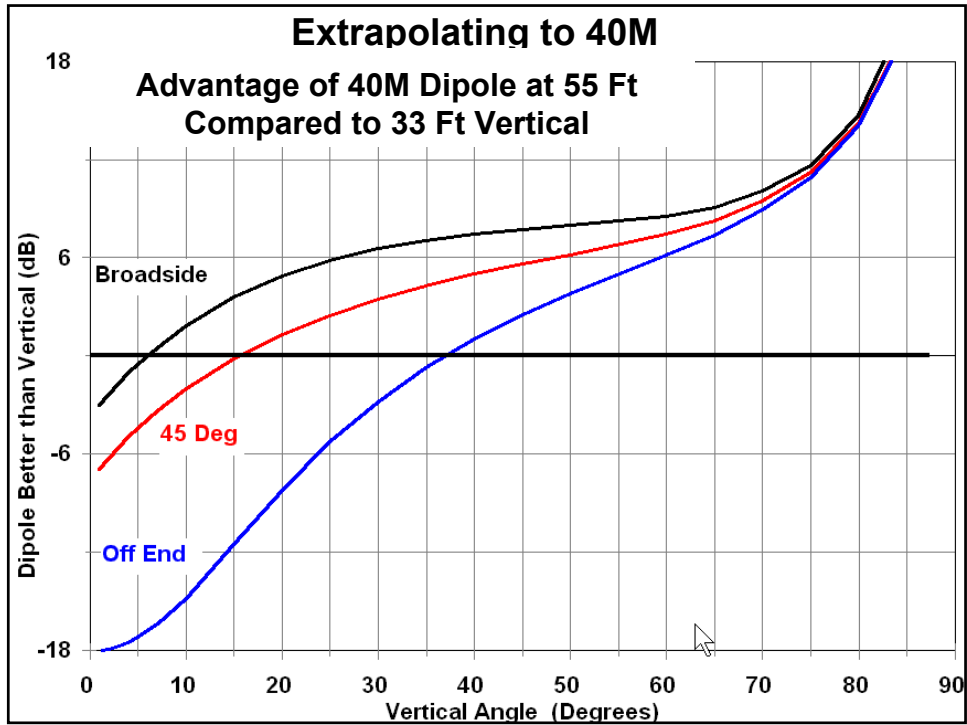
When to Use A Vertical

- **Larger commercial verticals on 40M–10M**
 - Install high, with good radial system
- **Efficient wires on 160-80M**
 - Low or on ground, with good radial system
 - Top loaded or full quarter wave
- **A few verticals don't need radials**
 - Cushcraft R7000 is center-fed, W1JR design
- **To fill in nulls off ends of a high dipole**

When Not to Bother With A Vertical

- **40M–10M when you can't mount it high and in the clear (high ground losses)**
 - High means at least $\lambda/8$
- **When it's physically shorter than $3\lambda/16$**
- **When you can't install at least three $\lambda/4$ radials for each band you want to operate**
- **When you can install high dipoles at right angles**
 - A high dipole will beat it, even loaded or bent

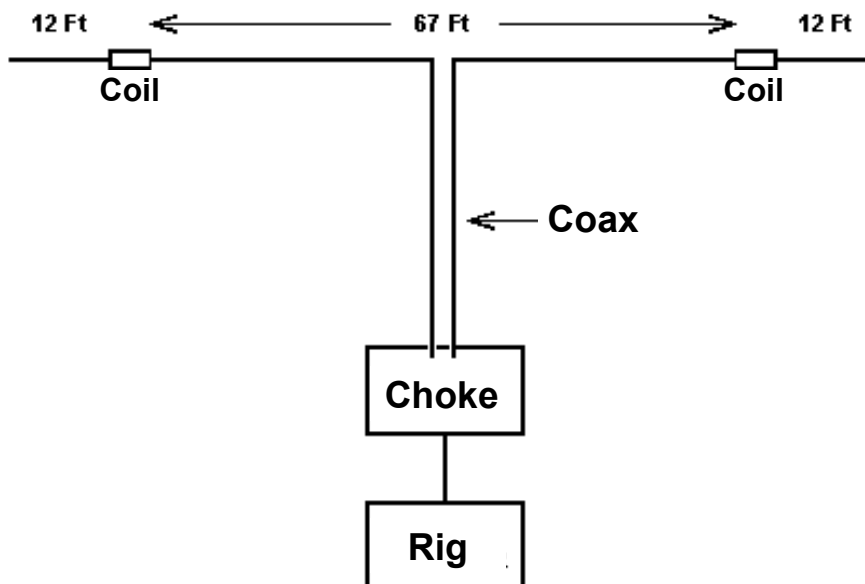




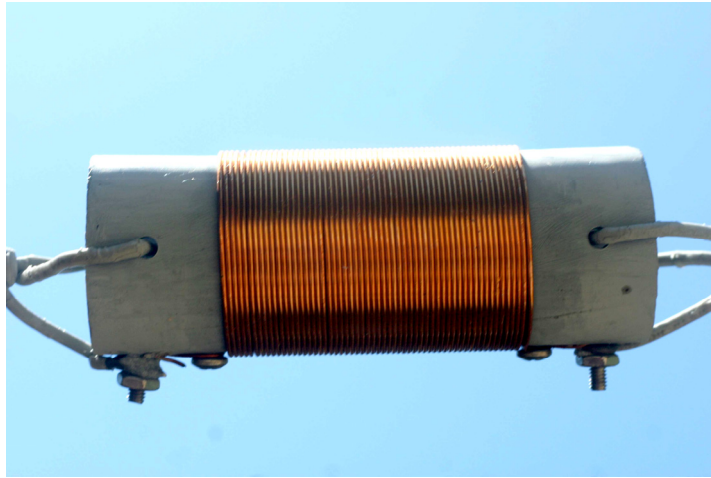
Try To Fit A Resonant Dipole First

- Well behaved pattern
- Inherently has gain in horizontal plane
- Vertical pattern depends on height
- For most QTHs
 - Higher is better on 40, 80, 160
 - Height not as important on 20-10
- Directivity tends to reduce noise
- Easy to feed with coax
 - Chokes can minimize receive noise, RFI

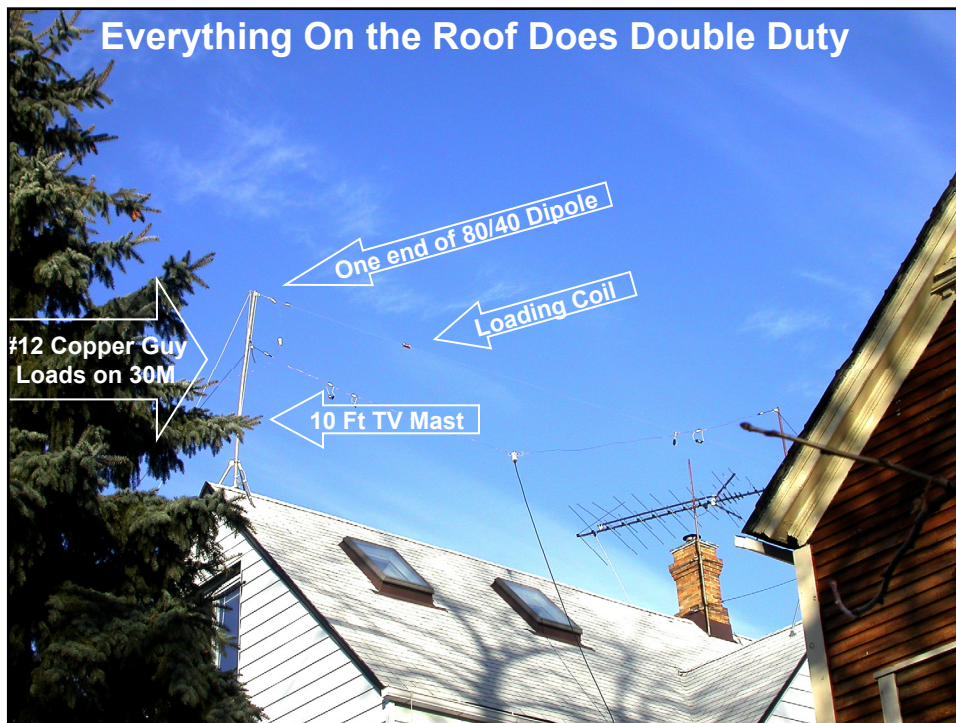
80/40 Shortened (Loaded) Dipole

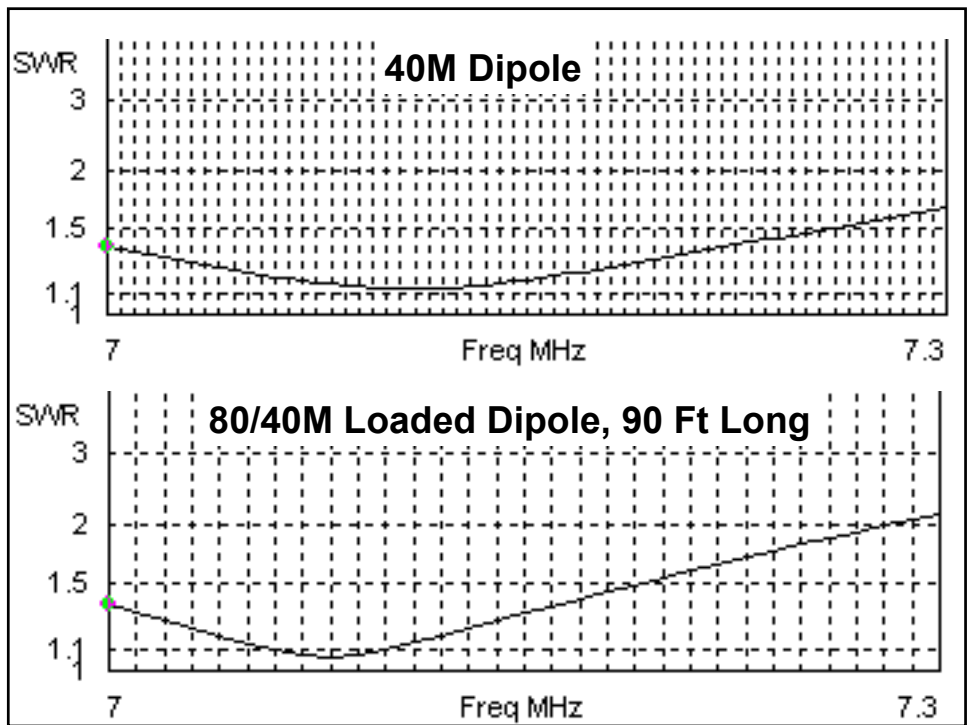


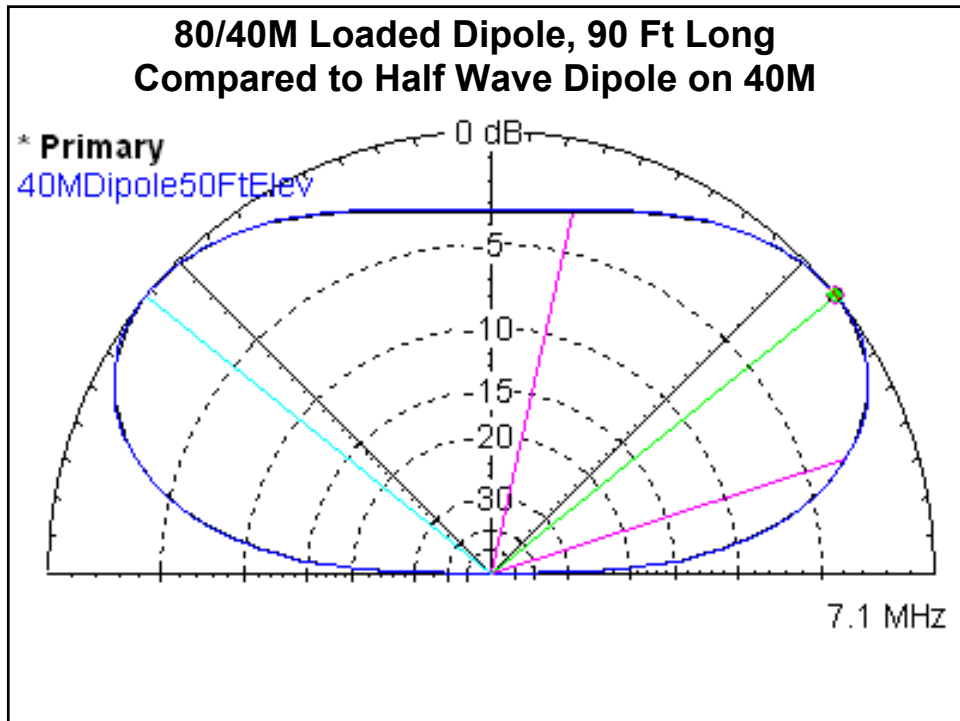
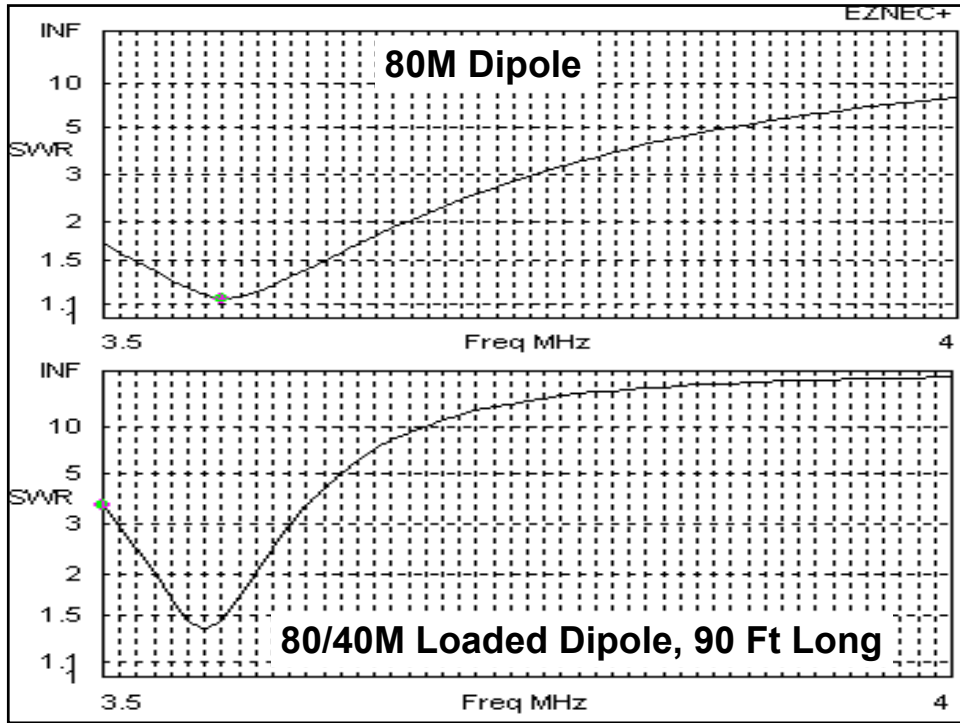
Loading Coil for short 80/40M Dipole



Everything On the Roof Does Double Duty



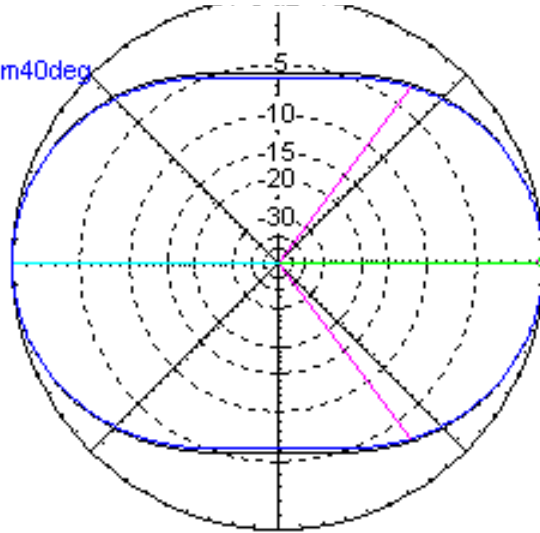




**80/40M Loaded Dipole, 90 Ft Long
Compared to Full Half Wave Dipole on 40M**

^ Primary

40MDipole50ftAzim40deg

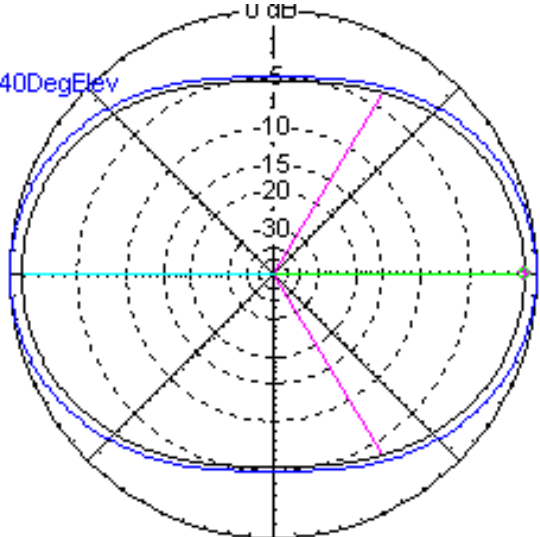


7.1 MHz

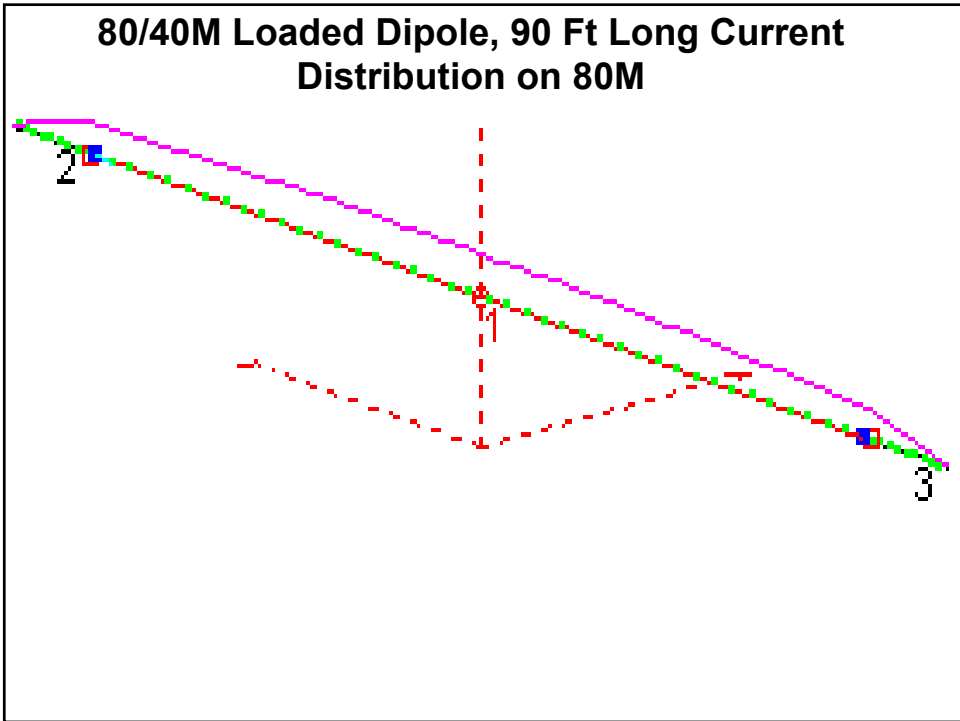
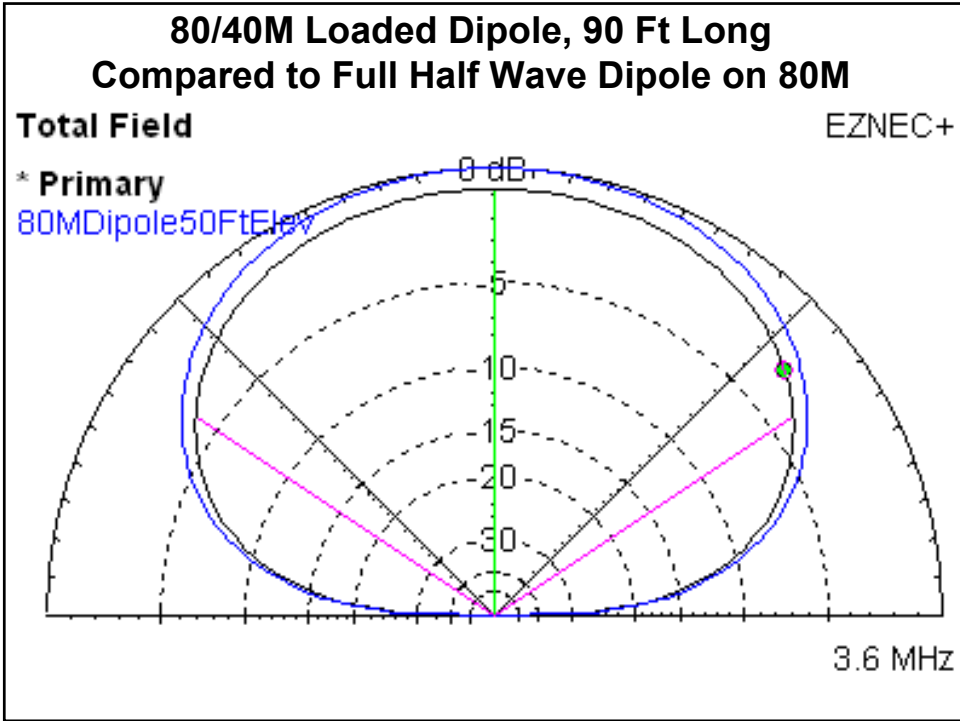
**80/40M Loaded Dipole, 90 Ft Long
Compared to Full Half Wave Dipole on 80M**

^ Primary

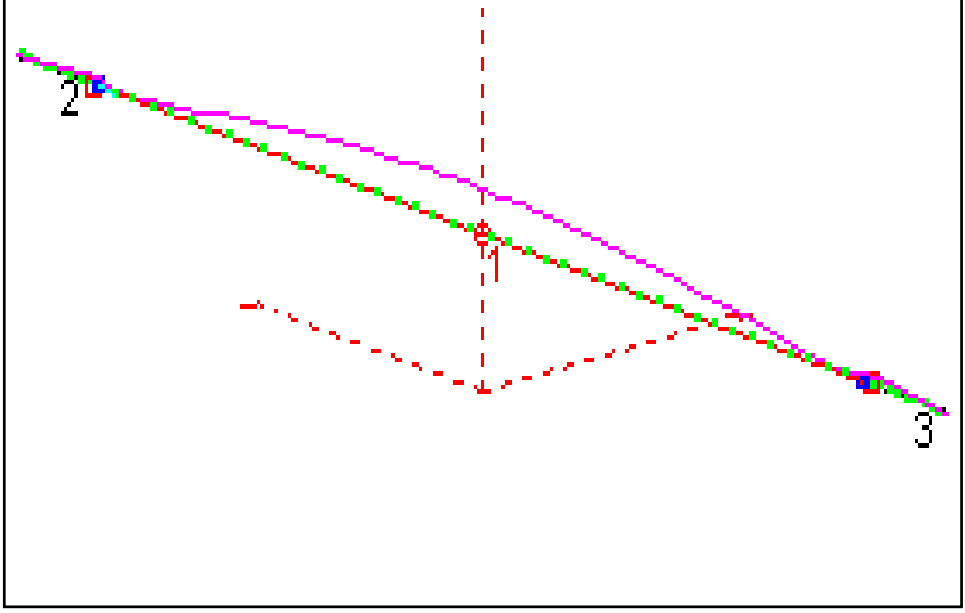
80MDipole50ftAz40DegElev



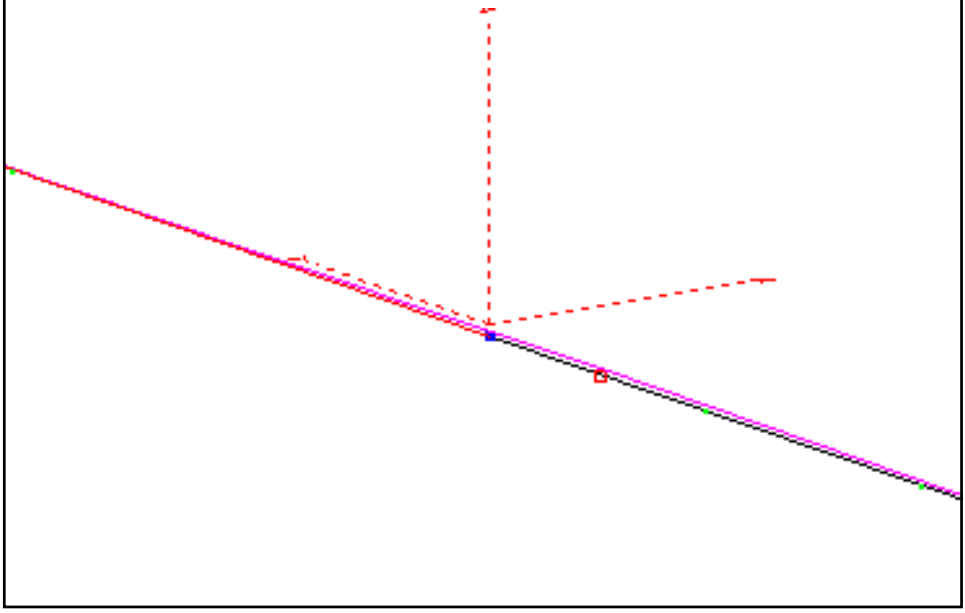
3.6 MHz



80/40M Loaded Dipole, 90 Ft Long Current Distribution on 40M



80/40M Loaded Dipole, 90 Ft Long Current Distribution on 40M



80/40M Loaded Dipole, 90 Ft Long Compared to Full Size Half Wave Dipole

- **40 Meters**
 - No significant difference in gain or pattern
 - Slightly less SWR bandwidth
- **80 Meters**
 - No significant difference in pattern
 - Gain about 0.8 dB lower
 - Much less SWR bandwidth
 - Greater feedline loss away from resonance

Build or Buy a Short Dipole?

- *Designing a Shortened Antenna* CT1EOJ
QST Oct 2003
- **Model it in NEC**
 - Tweak the design for multiband coverage
- **Buy from Barry, KU3X, Hypower Antenna
Company (QST, Internet) 2B8040L**
 - He's already done the design work

A 20/15/10 Trap Dipole Barely Fits between the two TV masts



Trap Dipoles

- **Traps are parallel resonant circuits**
 - Below resonance, they look inductive
 - So they act as loading coils on lower bands
- **A 3-band trap dipole fits in less space than a fan dipole**
 - 20/15/10 is about 26-27 ft (20M dipole = 33 ft)
- **Traps add some loss**
 - Typically 1-2 dB
 - A lossy antenna is better than no antenna
- **Traps reduce the SWR bandwidth**
 - Trim lengths carefully and use a tuner!

Fitting Full-Size Dipoles Into Less Space

- **Length of wire resonates the antenna**
 - Very little current near the ends of a wire
 - Bending simply distorts the pattern a bit (mostly fills in nulls)
- **Bend it at one or both ends**
 - Has least effect on pattern or efficiency
- **Bend it anywhere along its length**
 - A bit more effect on pattern (fills nulls)

Fitting Full-Size Dipoles Into Less Space

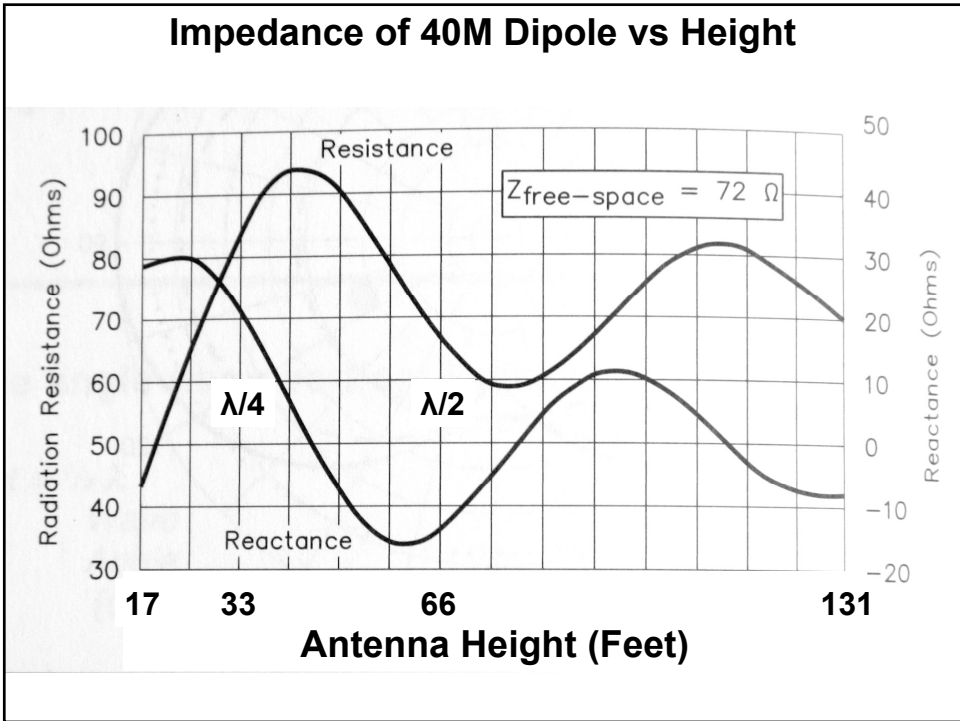
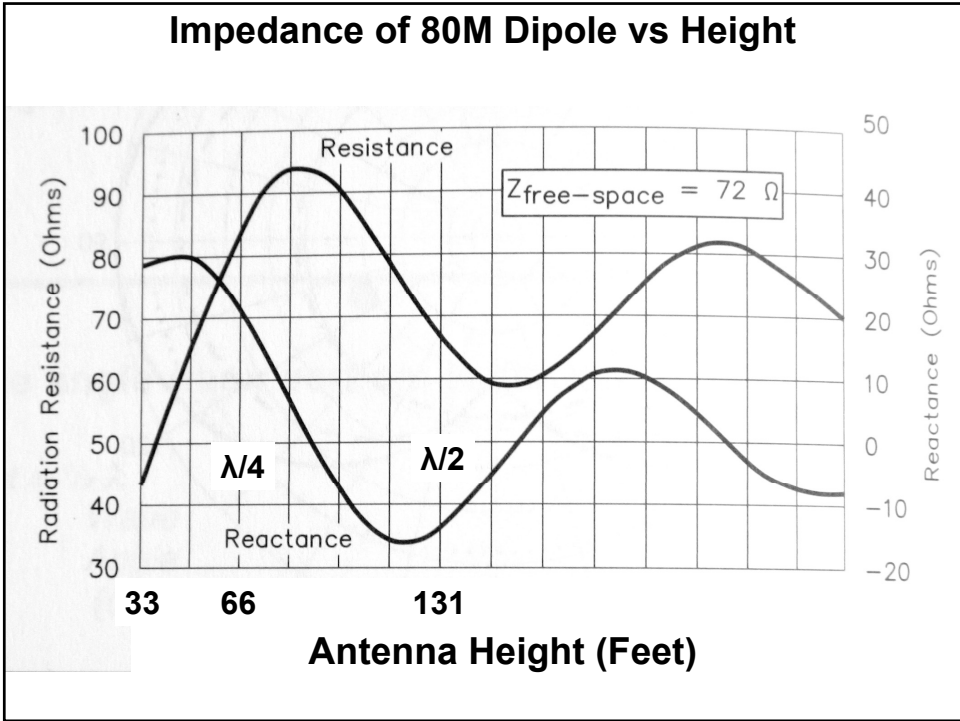
- **Use insulated wire**
 - about 2% less wire than bare copper
- **Use two or more wires in parallel ??**
 - Less than 1% shorter
 - 50% better SWR bandwidth
 - Nice, but not worth the trouble
- **Use bigger wire**
 - #10 only 0.5% shorter than #14
 - Stronger, but shortening doesn't matter
 - Doesn't change SWR bandwidth

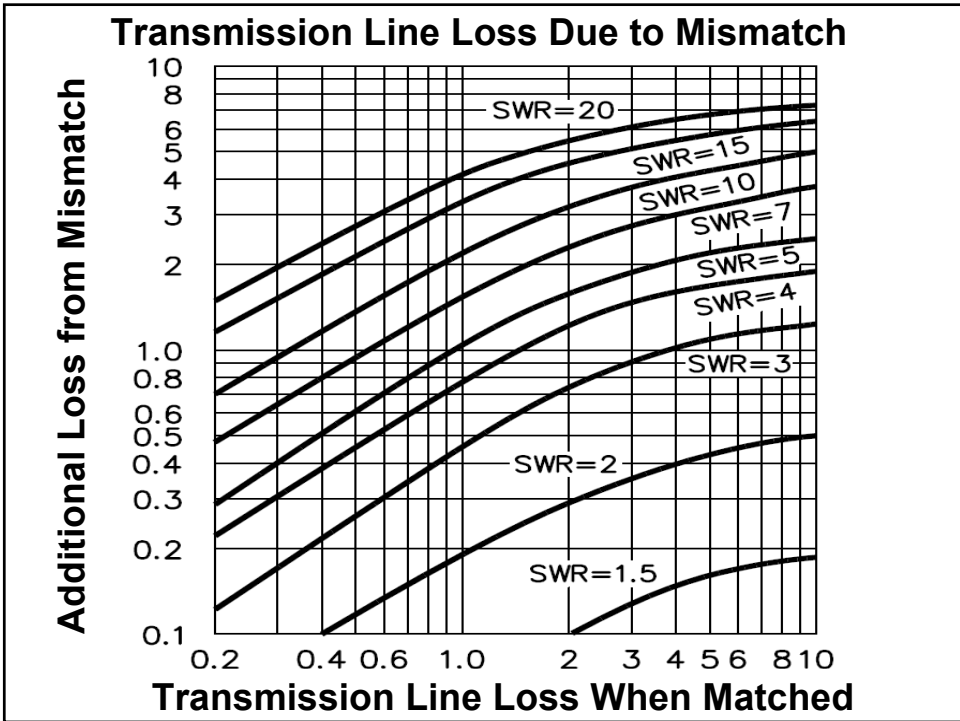
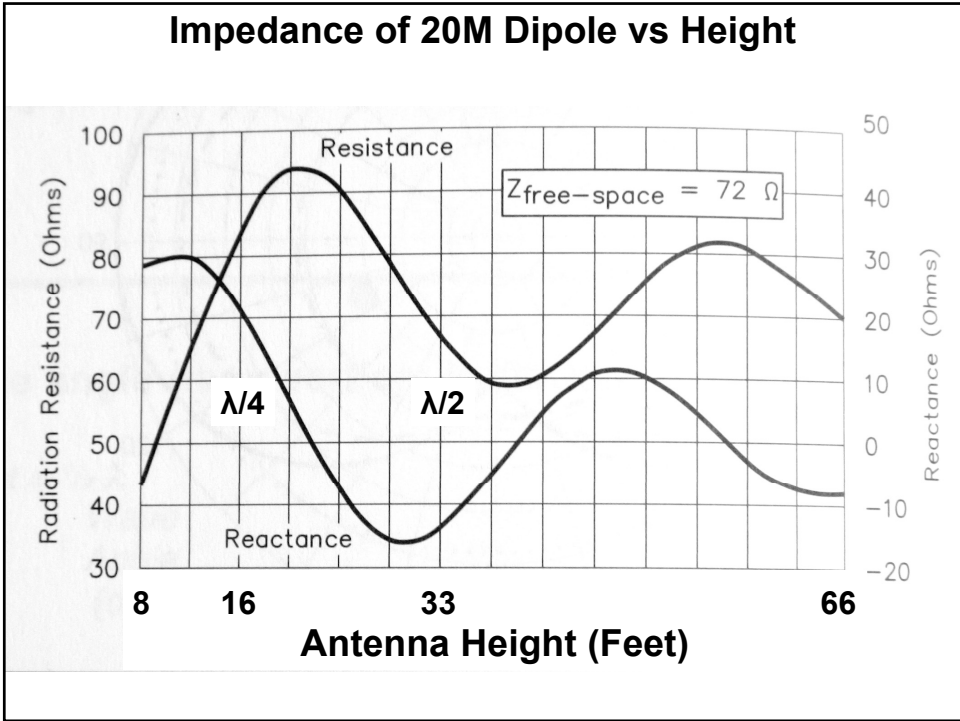
Fitting Full-Size Dipoles Into Less Space

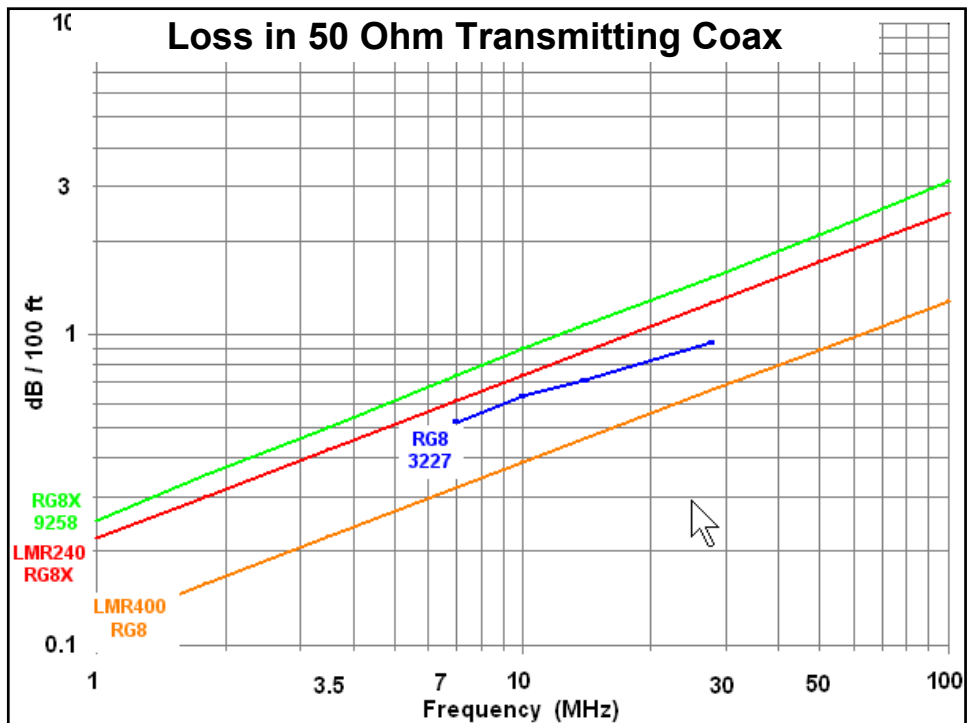
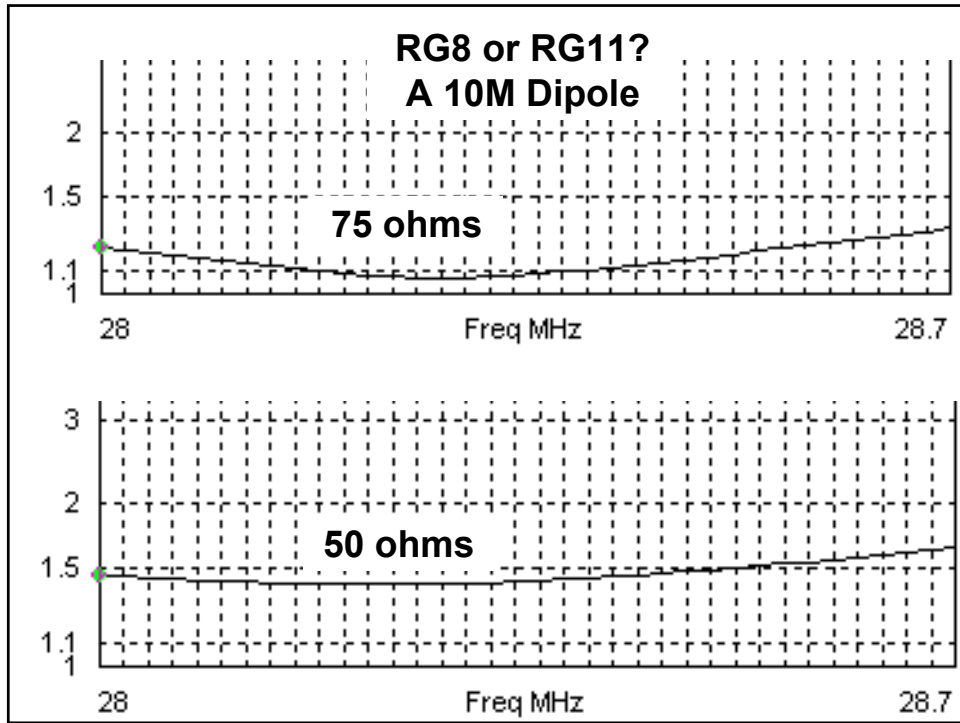
- **Hang from one end, let it slope**
 - Keep center as high as practical
 - Skews pattern
- **Hang as inverted-V**
 - Raises angle of radiation
 - Fills in nulls off the ends
 - Efficiency still good
 - Center is high, that's where the current is!
- **As end(s) get closer to the earth (or trees), a shorter wire will resonate**
 - capacitance to earth

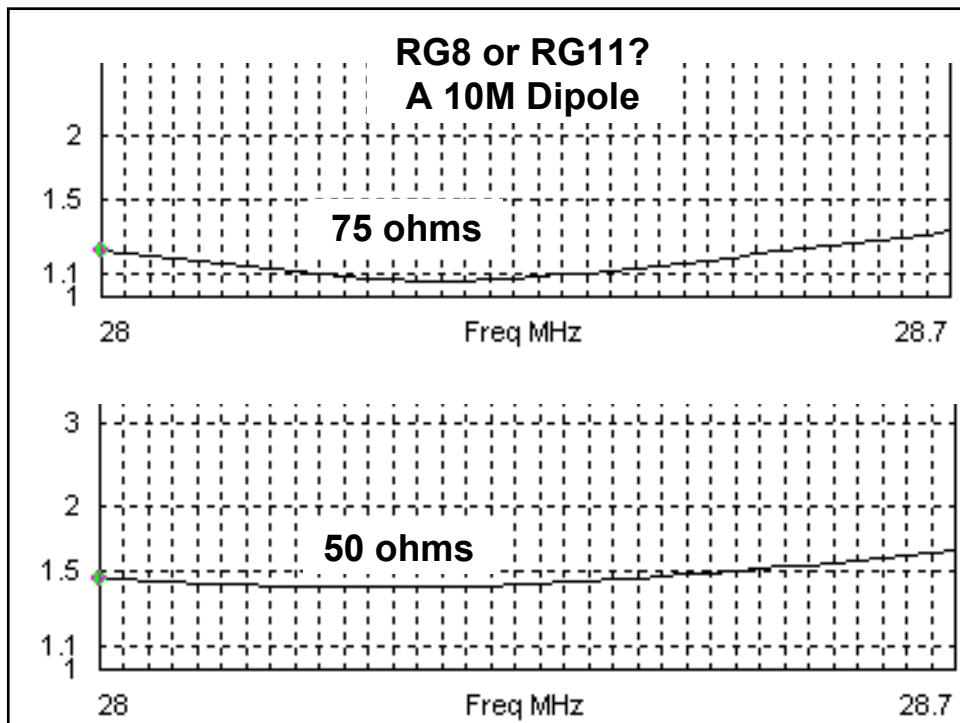
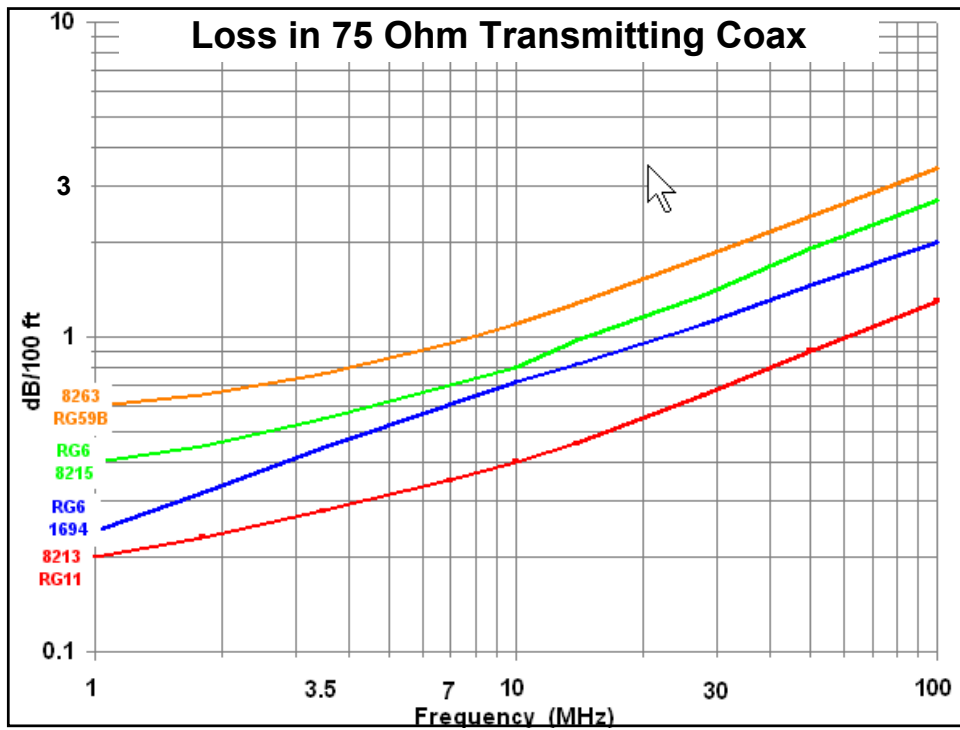
50 Ohm Coax or 75 Ohm Coax?

- **A Dipole in free space is a 72 ohm antenna!**
 - Proximity to earth changes the impedance
 - High dipoles are closer to 75 ohms
 - Low dipoles are closer to 50 ohms
- **Feedline SWR (and loss) depends on the match between feedline and antenna**
 - Use feedline that matches the antenna
- **XMTR will reduce power if mismatched**
 - Use an antenna tuner to make the rig happy









Build a Multiband Fan!

**My First 20/15/10 Fan Dipole in Chicago
Only up 25 ft, but a lot of noise on E Coast**



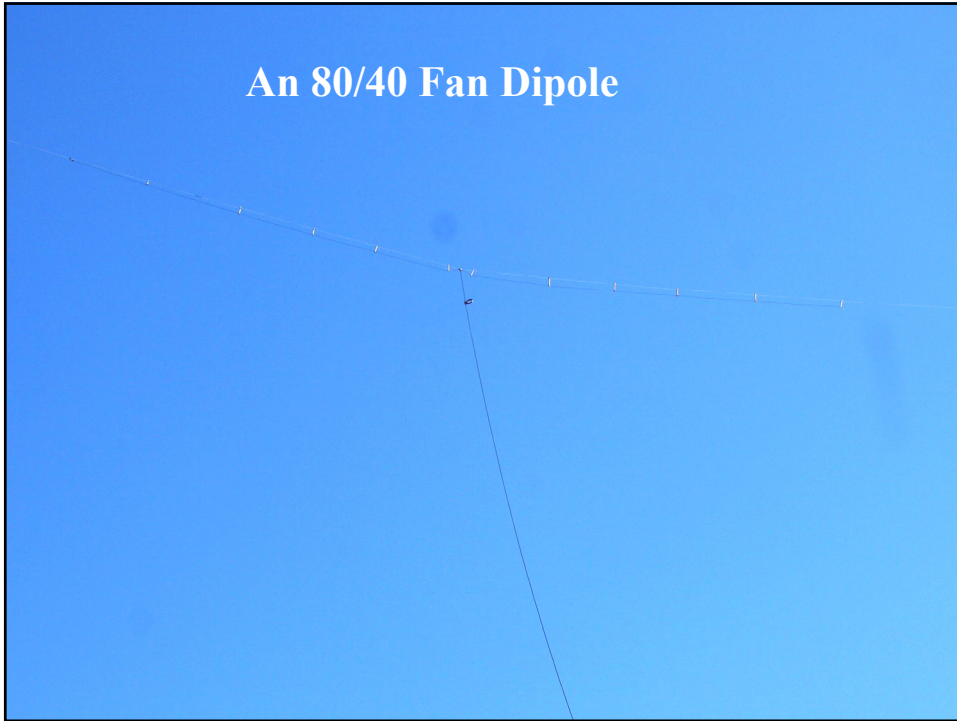
**A Fan Dipole
for 20/15/10**



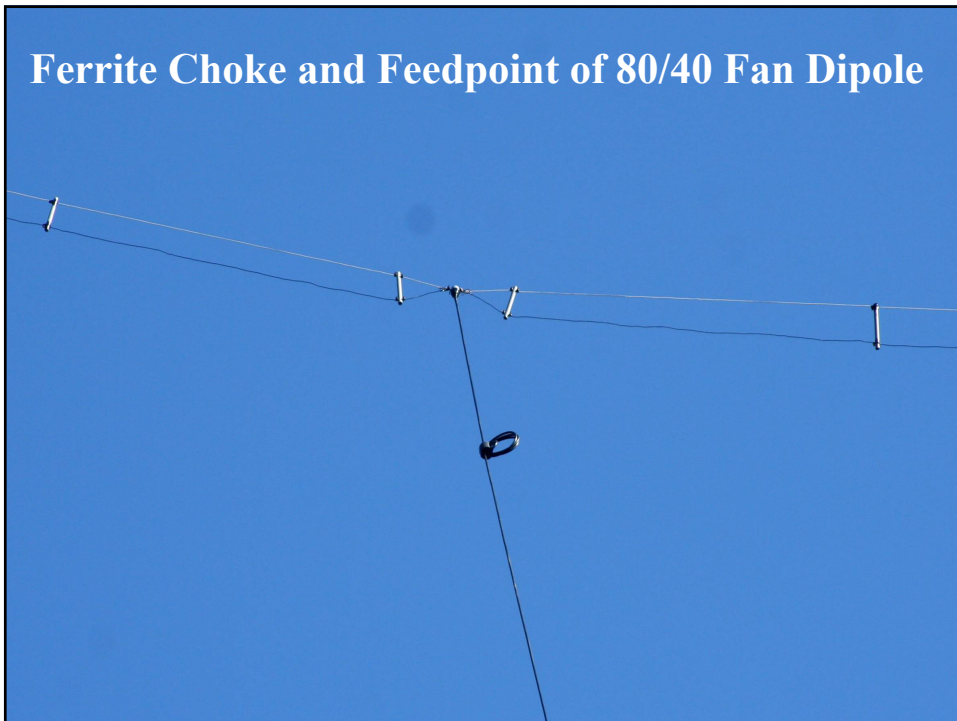
An 80/40 Fan Dipole



An 80/40 Fan Dipole

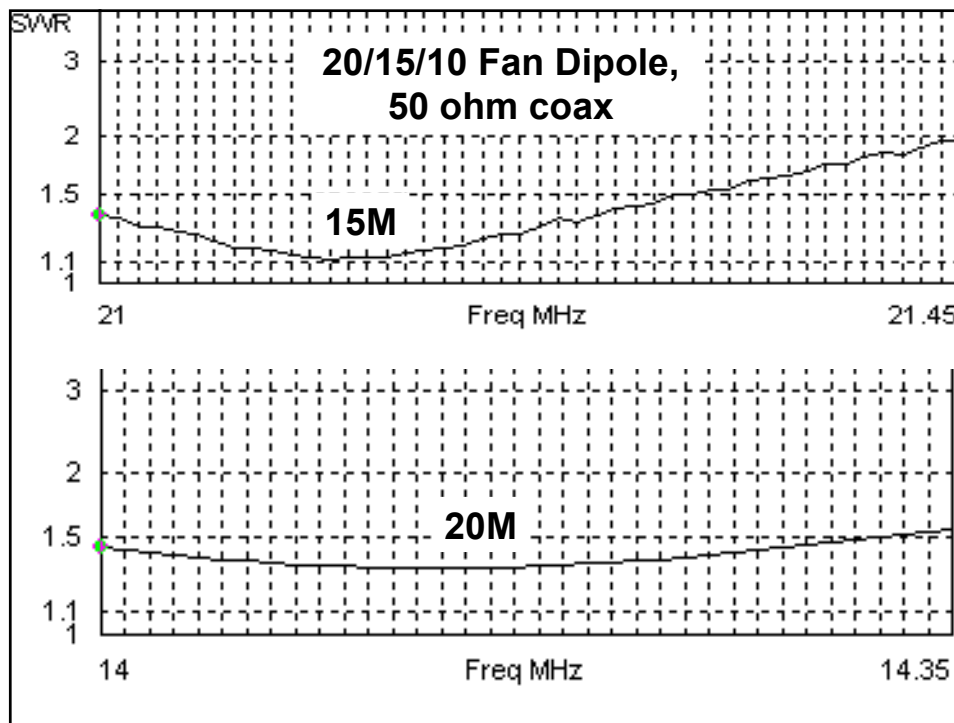


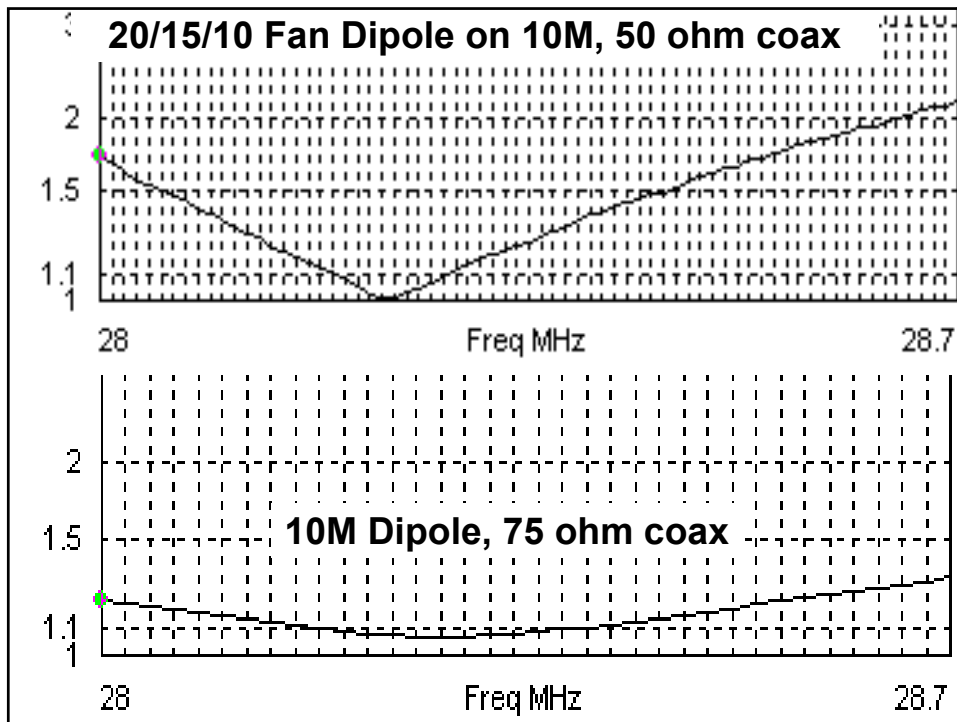
Ferrite Choke and Feedpoint of 80/40 Fan Dipole



Fan Dipoles – How They Work

- Same efficiency and pattern as a single dipole for each band
- Lowest frequency element has same SWR bandwidth as a single dipole
- Higher frequency elements have reduced SWR bandwidth (about 50%)
 - Length (tuning) more critical
 - Greater feedline loss at edges of band
- 20/15/10 fan looks like 50 ohms, even when very high





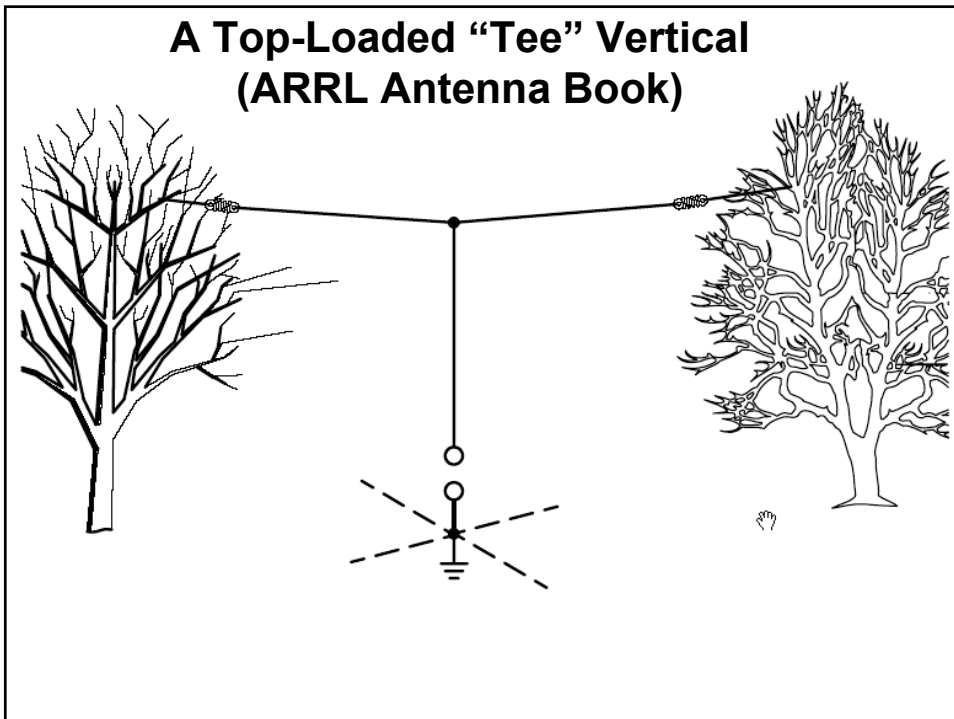
Improvising an End Fed Wire

- **Think about where most current will be**
 - Current must be zero at an open circuit
 - Current will be max $\lambda/4$ (and $3\lambda/4$) from an open circuit (low impedance, easier to match)
 - Could be closer if loading coils, capacitance
 - A high current point high and in the clear usually makes the antenna more efficient
 - Current must be near zero $\lambda/2$ (and λ) from an open circuit
- High current parts of antenna radiate
- High current points easier to match

Feed A Random Wire From the End

- You will need an antenna tuner
- Avoid half wavelengths (high Z at the feedpoint, harder to match to XMTR)
- The lower the frequency, the greater the benefit of increased height
- You do need a radial system

A Top-Loaded "Tee" Vertical (ARRL Antenna Book)



A Top Loaded Vertical on 80/160

- **Inverted L**
- **“Tee” – vertical**
- **Load it against radials or a counterpoise**
- **Use what you can install**
 - **It doesn't need to be perfect**
 - **Longer/bigger is better**
 - **Do your best and call CQ!**

A Top Loaded Vertical on 80/160

- **Ideally would be quarter wave vertical**
 - **70 ft on 80M**
 - **135 ft on 160M**
- **Few of us can do that, so go as high as you can and**
 - **bend it in one direction (inverted L)**
 - **Bend it in two directions (Tee)**

so that it looks like a quarter wave to the transmitter

A Top Loaded Vertical on 80/160

- **Split the difference and load a Tee or inverted L on both 80 and 160 (w/tuner)**
 - 90-100 ft is $3/8\lambda$ on 80M, $3/16\lambda$ on 160M
 - 160-170 ft is $5/8$ on 80M, $5/16$ on 160M

Radial Systems

- **Provide a return for the fields and currents produced by an end-fed antenna**
- **The earth is lossy, burns transmitter power**
- **Use enough radials so that fields and current are in copper, not earth**
- **A few resonant radials work if elevated**
- **Many needed if on ground**

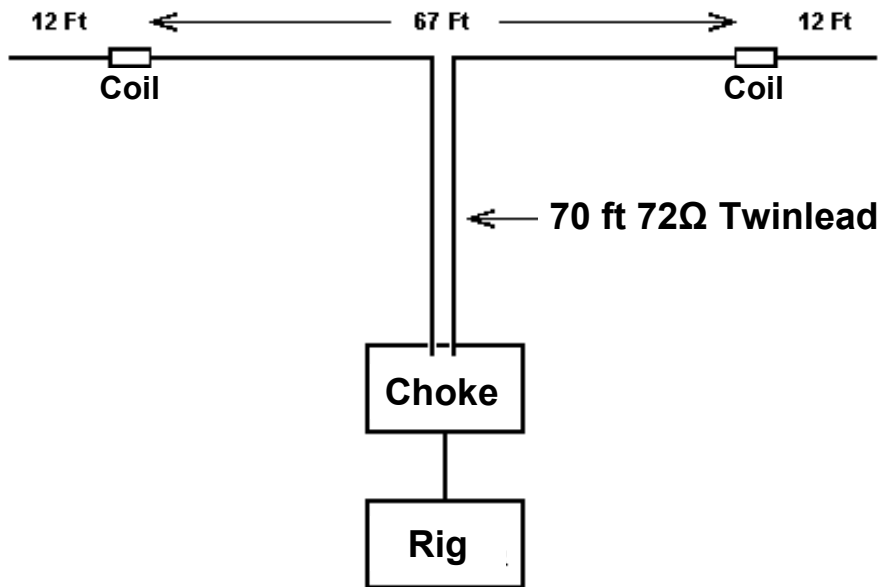
Improvising Antennas

- Feed it against radials or a counterpoise
 - A ground stake doesn't help
 - More wire close to the feedpoint is better
 - A lot of short wires are better than a few long ones
 - Symmetry much less important than quantity
 - Wire diameter enough it won't break
 - Do the best you can and call CQ!
- To learn more about radial systems, study N6LF's website

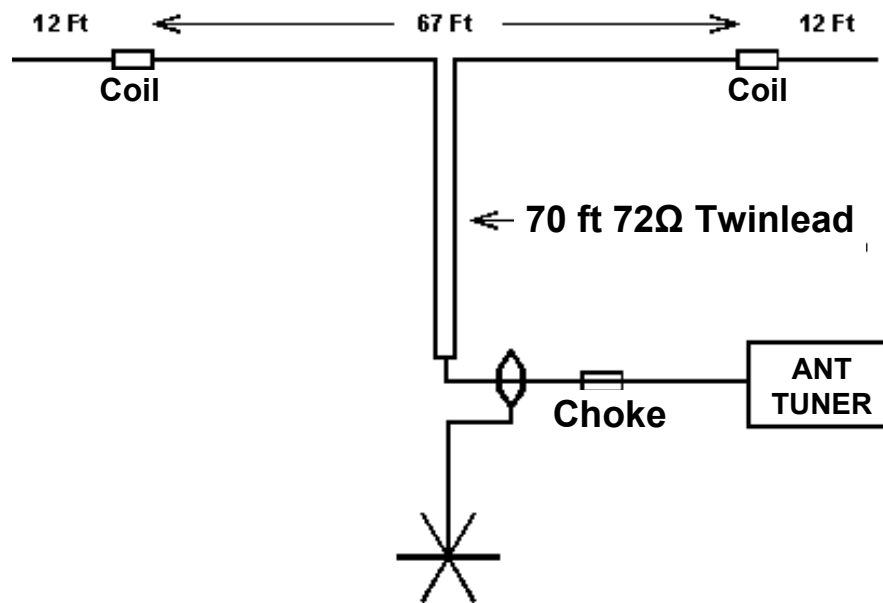
On Ground Radial Systems (ARRL Antenna Book)

<u>Number</u>	<u>Length</u>	<u>Loss</u>	<u>Z</u>
0		10 dB ?	90 Ω ?
16	0.1 λ	3 dB	52 Ω
24	.125 λ	2 dB	46 Ω
36	.15 λ	1.5 dB	43 Ω
60	0.2 λ	1 dB	40 Ω
90	0.25 λ	0.5 dB	35 Ω

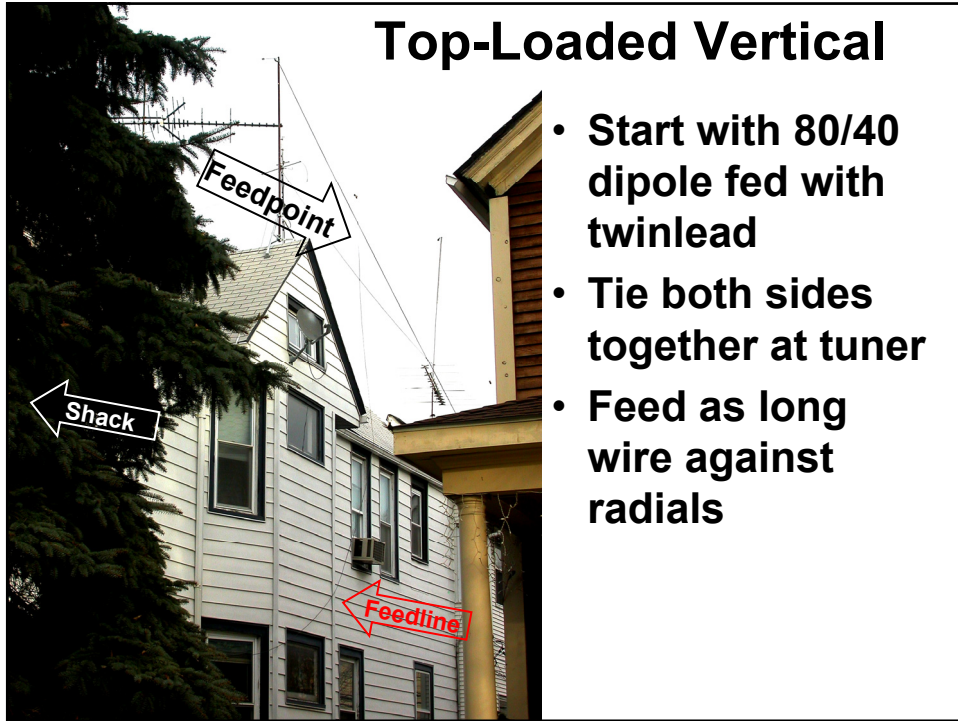
80/40 Loaded Dipole



Top Loaded Vertical on 160M

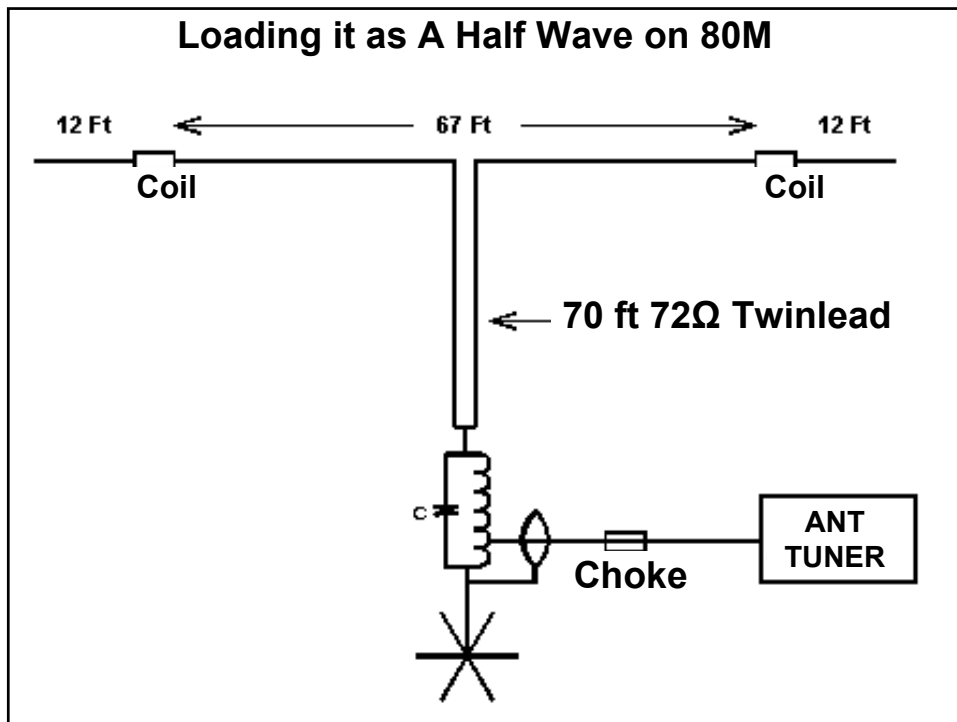


Top-Loaded Vertical



Wrought Iron Fence was Counterpoise for Vertical (KK9H uses HVAC ducts and plumbing system!)





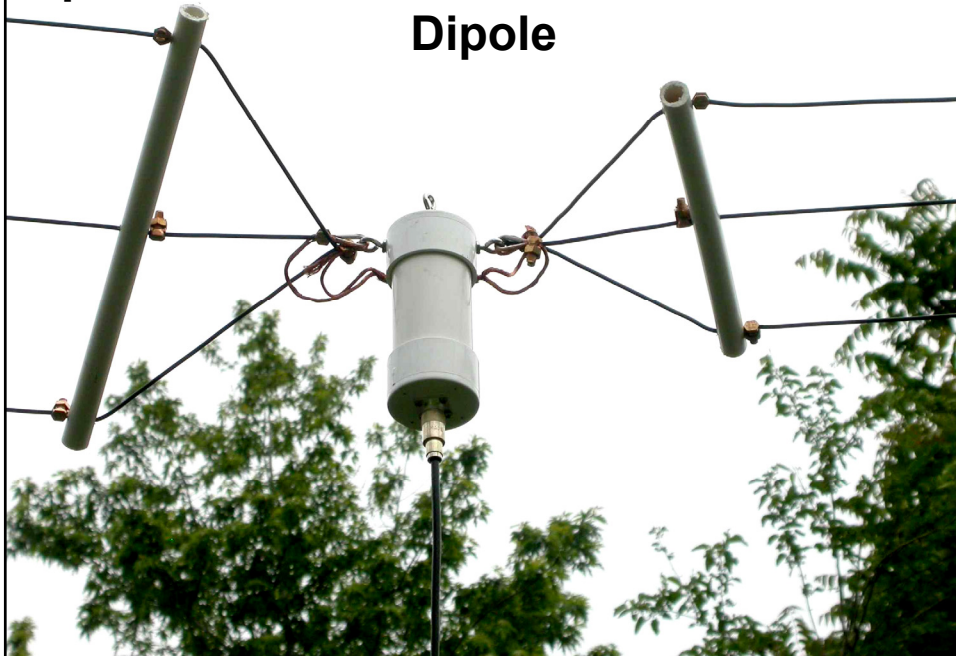
Building Wire Antennas

- **Use Insulated House Wire (THHN)**
 - #10 or #12 for heavy loads, long spans
 - #14 for lighter antennas
 - #18 or even #22 for stealth!
- **Use thimbles where wire bends to minimize stresses**
 - The Wireman 800, 800A
- **Avoid “Flex-Weave”**
 - I’ve used a lot of it – every antenna has broken!

Building Wire Antennas

- **Don't solder a connection that can flex**
 - Soldering makes copper brittle, and it will break!
- **Use Split Bolt Connectors for both mechanical and electrical connections**
 - McMaster-Carr 6921K56 (\$1.89 each, 25 lots)
 - Lowe's, Home Depot (about \$3 each)
- **Tape up connections to minimize corrosion**

Split Bolt Connectors at Center of a Fan Dipole



Building Wire Antennas

- **End insulators – use eggs**
 - RF Connection
- **If you must climb to hang it, use a pulley!**
 - Marine pulleys work well (\$15 - \$25)
- **Support rope**
 - UV resistance, strength, big enough to pull
 - 3/16-inch for light antennas, low tension
 - 5/16-inch for heavy ones you need to pull
 - DX Engineering, Davis RF

A Good Center Insulator is Hard to Find!



Building Dipoles

- **Center Insulator**
 - Mechanical Strength
 - Electrical connections
 - Weatherproof
 - Corrosion
- **A Good Center Insulator is Hard to Find!**
 - (You always get the other kind)
 - Wireman 801 is best of a bad lot
- **Avoid commercial “baluns”**
 - Wind a much better coax choke using guidelines in my Choke Cookbook

Building Fan Dipoles

- **Spacers are easy to build**
 - ½-inch UV-resistant PVC conduit, cut into
 - 15-inch lengths for 3-wire fans
 - 9-inch lengths for 2-wire fans
 - Separate wires by about 7 inches
 - Drill holes for wire to pass through
- **For 20/15/10 fans**
 - Spacer near center insulator
 - Spacer at end of 10M element
 - Spacer at end of 15M element

Building Fan Dipoles

- **For 80/40 fans**
 - Spacer near center insulator
 - Spacers about 6 ft apart
- **Length of elements**
 - Build according to usual formulas for the wire you're using, but cut a little long and trim to length after it's been in the air
 - Include all wire starting from the coax connector
 - Remember that insulated wire lowers the resonant frequency about 2%
 - I've not seen interaction between elements

Getting Wires Into Trees

- **Climb the tree, install a pulley (Best)**
 - It will stay up longer, easy to change antenna
 - Allows a counterweight for wind motion
 - Least fraying of support rope
 - Climbers can be expensive (\$500/day typical)
- **Use a launcher**
 - Put heavy fishing line over a branch
 - Pull up heavier line
 - Pull up the final support rope

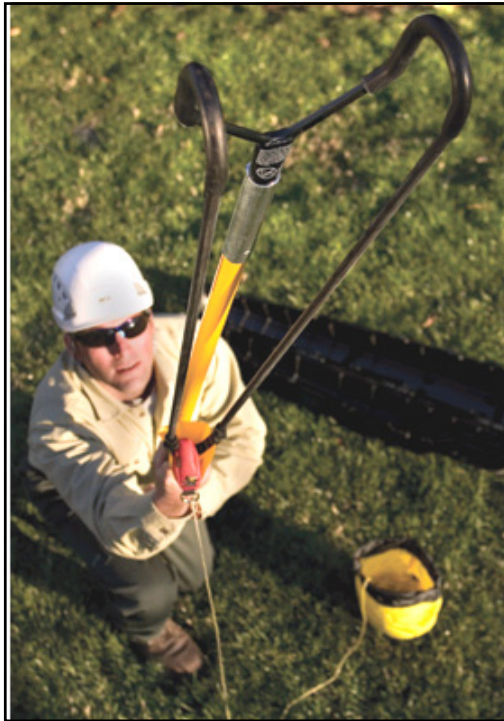


- **Tennis Ball Launcher \$110 - \$350**
 - Good for 200 ft
 - www.antennalaunchers.com

EZ Hang Launcher \$100 - \$130

<http://ezhang.net>





- **A super slingshot on an 8 ft pole**
 - 2 – 4ft sections
- **Sherrill Tree Service**
 - About \$160 w/line and weights
 - <http://sherrilltree.com>
 - Good for 80 – 100 ft

Installing a Pulley with a Launcher

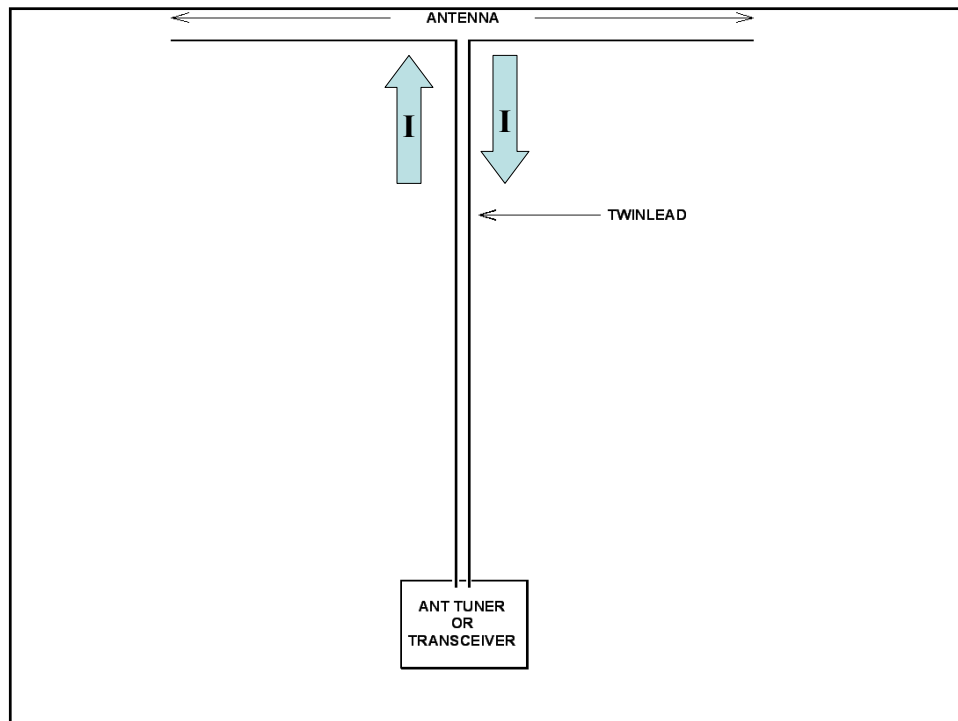
- **Launch heavy fishing line over a branch**
- **Pull up heavier line, then final support rope**
- **Make a continuous loop of heavy support rope from top to ground**
- **Attach pulley to the loop**
- **Run final support rope through pulley**
- **Pull pulley, with support rope, up to the top**
- **Attach final support rope to antenna**
- **Now you can use a counterweight with minimal abrasion of support rope**

Why Not an All Band Wire Fed with Twinlead?

Understanding Common Mode and Differential Mode Currents on Transmission Lines

Differential Mode Current

- Transmission line carrying power from transmitter to antenna, or from antenna to receiver
- Signal is voltage between the two conductors
- Current flows out on one conductor and returns on the other

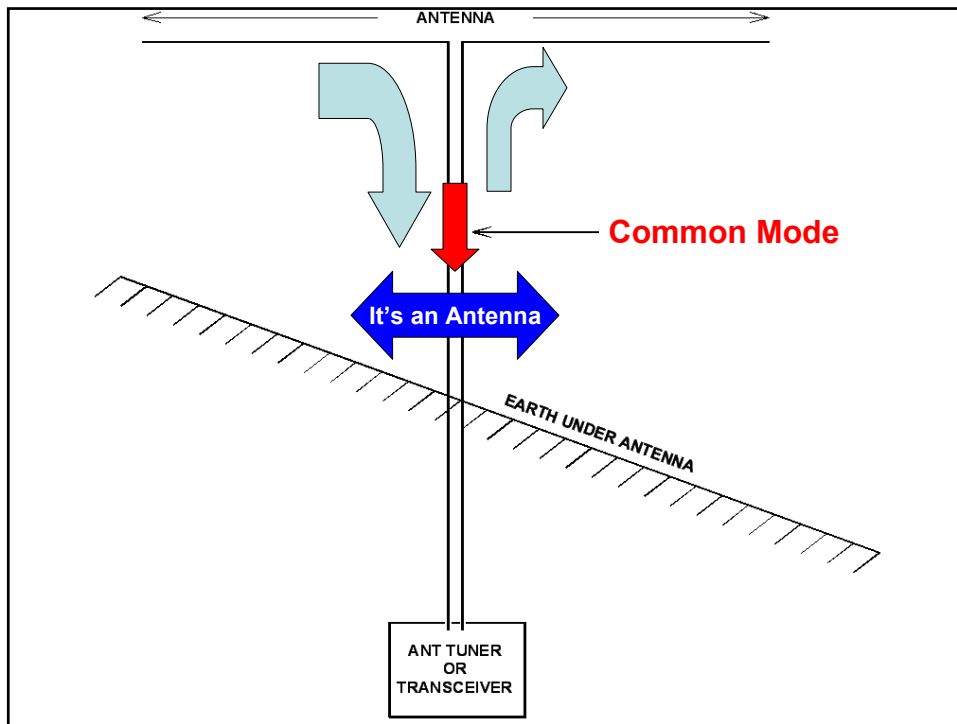


Differential Mode Current

- Transmission line carrying power from transmitter to antenna, or from antenna to receiver
- Signal is voltage between the two conductors
- Current flows out on one conductor and returns on the other
- Fields exist between the two conductors
- No radiation from ideal line
 - Field of outgoing conductor cancels field of return conductor

Common Mode Current

- Equal and flowing in the same direction on all conductors of balanced lines
- Current flows lengthwise on the line
 - No cancellation of one current by another, because they're in polarity
- Line acts as long wire antenna
 - It radiates and it receives



Ham Antennas and Balance

- Most ham antennas are unbalanced by their surroundings, even when fed by a balanced source and line

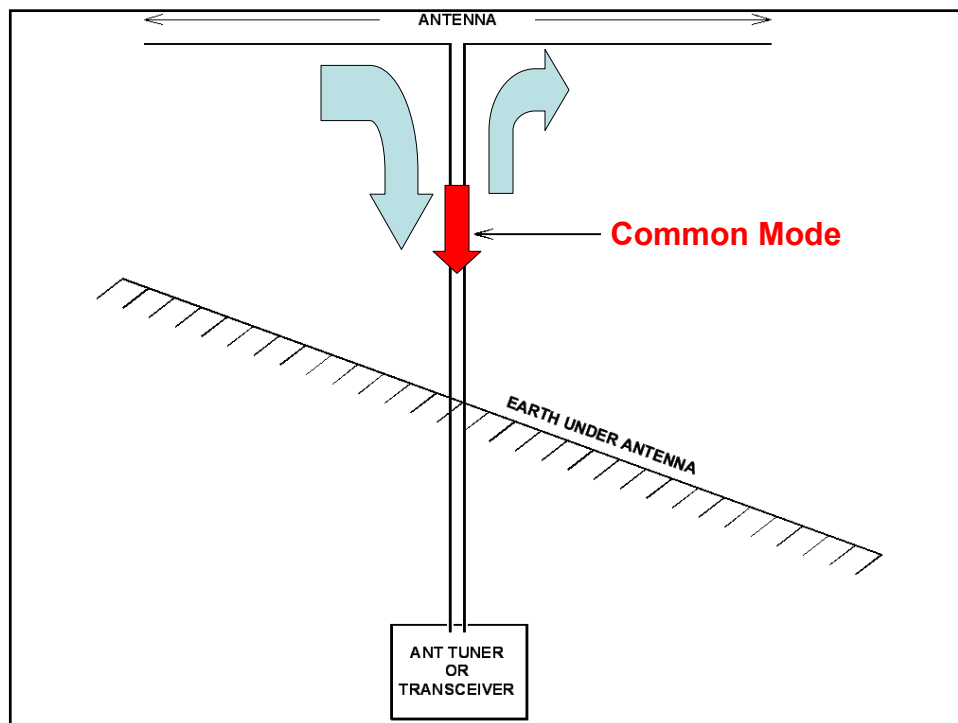
What Makes a Circuit Balanced?

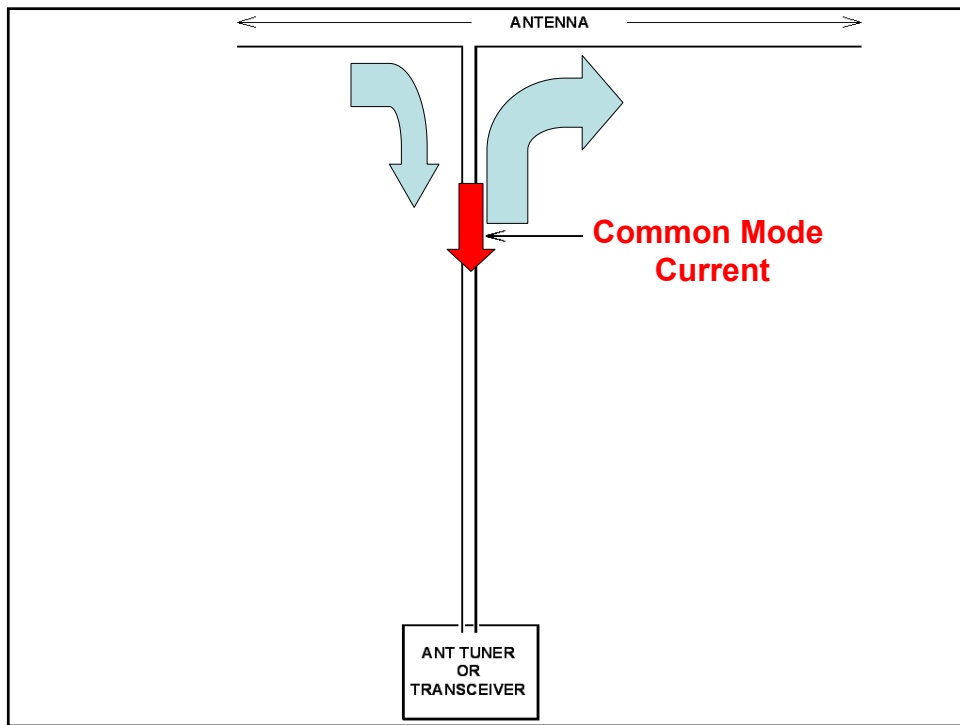
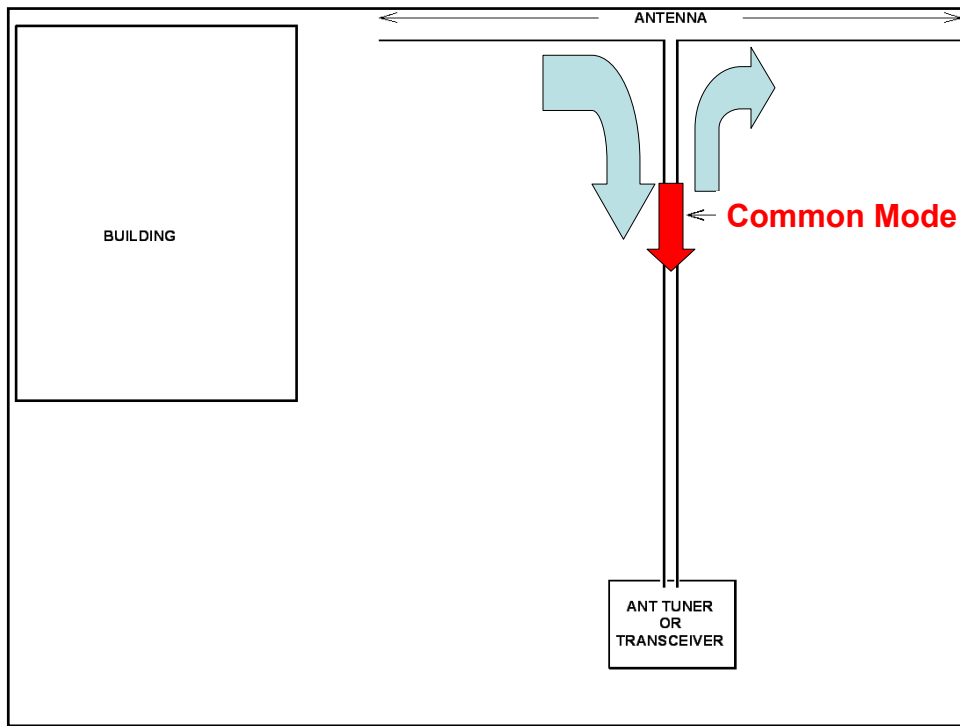
What Makes a Circuit Balanced?

- The impedances of each conductor to the reference plane are equal
- Balance is not defined by voltage or current
- Imbalance impedances cause unbalanced currents

Ham Antennas and Balance

- Most ham antennas are unbalanced by their surroundings, even when fed by a balanced source and line
 - Unequal capacitances to nearby conductors
 - Unequal inductive coupling to nearby conductors
 - Trees, buildings, towers, terrain
 - Feedline comes off at an angle
 - Coax is not a part of these imbalances





Unbalanced Antennas and Lines

- **If the antenna is unbalanced**
 - Unequal voltage and current to earth
 - Unequal currents on the feedline
 - The difference is common mode current, and it radiates from the line
- **Coax did not cause the imbalance in these antennas!**
- **Coax simply adds to the imbalance**

The Fields around Coax and Twinlead are Very Different

Coax is Special

- All the differential power (and field) is confined inside the coax
- All the common mode power (and field) is outside the coax
- A ferrite core surrounding coax sees only the common mode power (and field)

Coax is Special

- Skin effect splits the shield into two conductors
 - Inner skin carries differential mode current (the transmitter power)
 - Outer skin carries common mode current (the current due to imbalance)

Twinlead Has Leakage Flux from Differential Current

- **This leakage flux is not confined to the region between the conductors, but instead spills to the area immediately surrounding the conductors**
- **Leakage flux causes very little radiation, but it will cause heating in a lossy medium!**
 - Like a ferrite core

How Much Leakage Flux?

- **Depends on mutual coupling between conductors**
 - Depends on conductor-to-conductor spacing
 - How close together can conductors be?
- **Coupling coefficient of 60-70% typical**
 - 30-40% leakage flux in best balanced cables
 - 50% or more in ladder line

We'll talk more about all this later on

Now We Can Talk About Common Mode Chokes!

What's a Common Mode Choke?

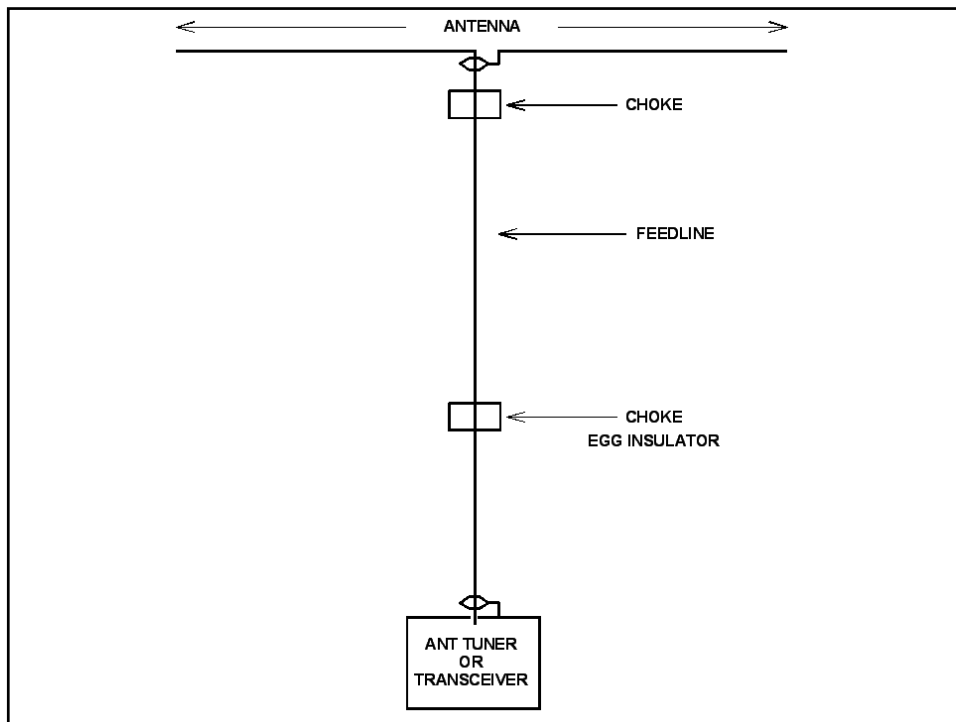
- **A circuit element that reduces common mode current by adding a high impedance in series with the common mode circuit**
 - **Reduces radiation from the cable**
 - **Reduces reception by the cable**

Some Common Mode Chokes

- **A coil of coax at the antenna**
- **A string of ferrite beads around coax (Walt Maxwell, W2DU)**
- **Multiple turns of transmission line through a toroid (Joe Reisert, W1JR) or stack of toroids (W1HIS, K9YC)**
- **Most 1:1 “baluns” are common mode chokes**

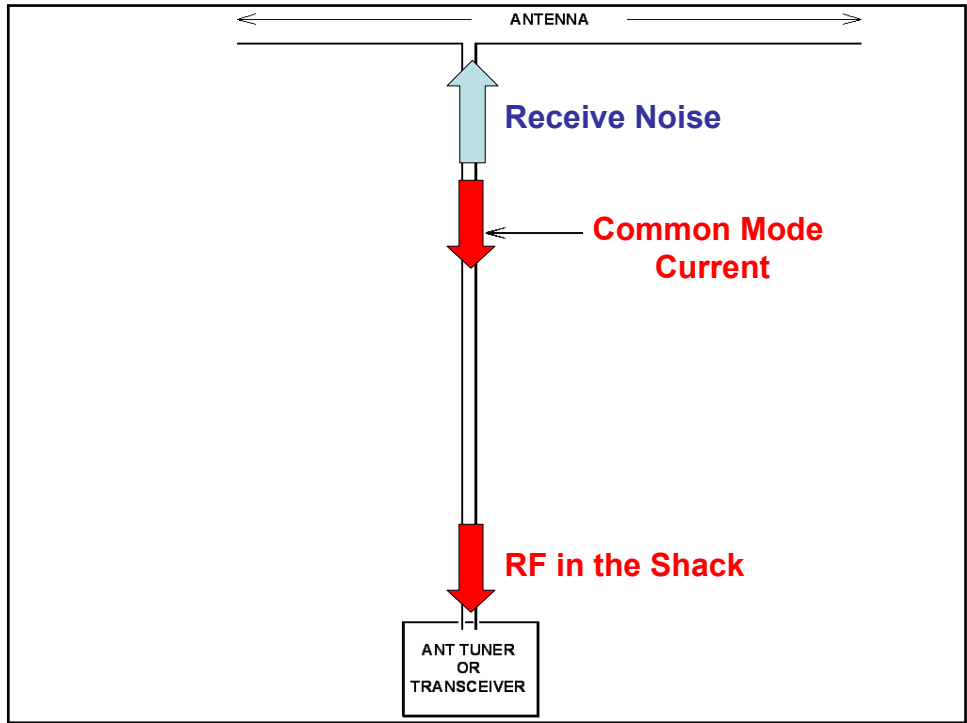
Some Common Mode Chokes

- **Some 2:1, 3:1, and 4:1 “baluns” are also common mode chokes**
 - **But the few I’ve measured aren’t very good common mode chokes**



Why Transmitting Chokes?

- Isolate antenna from its feedline
- Reduce receive noise
- Keep RF out of the shack
- Minimize antenna interaction
 - SO2R, Multi-multi
 - Dipole feedline and vertical antenna



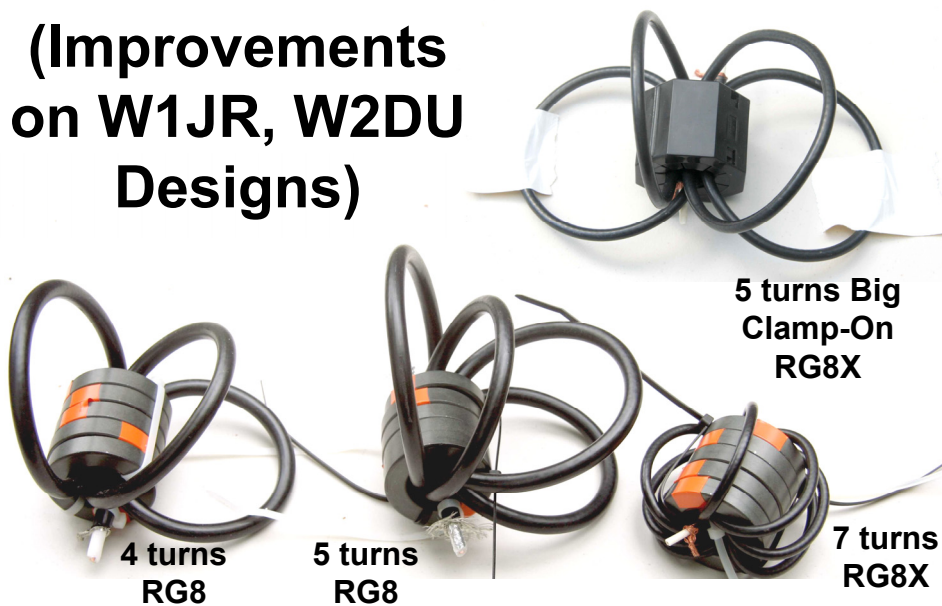
“Strings of Beads” (W2DU, W01YH Baluns)



A String of Different Beads



K9YC Chokes (Improvements on W1JR, W2DU Designs)



Why Not Twinlead?

- You can't put a choke on it!

So:

- More receive noise
- More RF in the shack
- More RFI to your neighbors
- More antenna interaction
- More loss when it's wet

References

- **A Ham's Guide to RFI, Ferrites, Baluns, and Audio Interfacing** Self-published tutorial (on my website)
- **Transmitting Chokes** (Power Point pdf) (on my website)
Applications notes, tutorials, and my AES papers are on my website for free download
<http://audiosystemsgroup.com/publish>

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