ANTENNA BASICS FOR BEGINNERS

INTRODUCTION

VERTICALS

MULTIBAND VERTICALS

DIPOLES

MULTIBAND DIPOLES

RF CHOKES

HOW DO ANTENNAS WORK?

An Antenna Is A Basic Transducer

For transmitting, you generate an RF signal on a conductor.

-**Electric** fields arise from a voltage rapidly changing

-**Magnetic** fields arise from a current rapidly changing

Generally people don't think of radio-frequency radiation in terms of discrete particles (oscillating electrons and photons) -they typically use the **wave model** instead, as it's much easier to use.

An efficient resonant antenna (1/4 wavelength or longer) produces a large-amplitude EM wave for a given feed power, and produces little heat. An inefficient antenna produces a small-amplitude EM wave for the same feed power, and converts most of the power into heat.

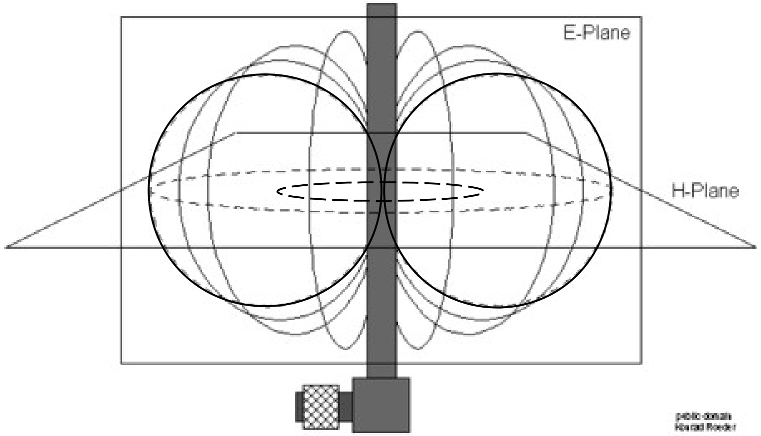
For receiving, the same resonance issues apply. It's just that when receiving, the currents induced on the antenna by the passing EM field cause a terminal voltage at the feedpoint of the antenna, which generates a propagating signal down the coax to the receiver's input amplifier circuit.

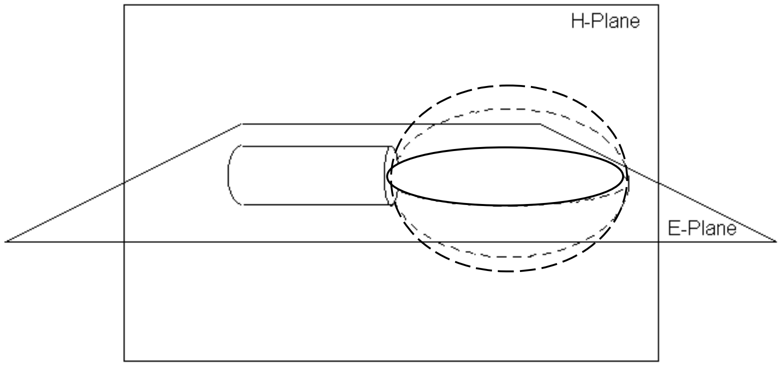
VERTICAL and HORIZONTAL POLARIZATION

The **Electric field** or E-plane determines the polarization or orientation of the radio wave.

For a vertically-polarized antenna, the E-plane usually coincides with the vertical/ elevation plane.

For a horizontally-polarized antenna, the E-plane usually coincides with the horizontal/azimuth plane.

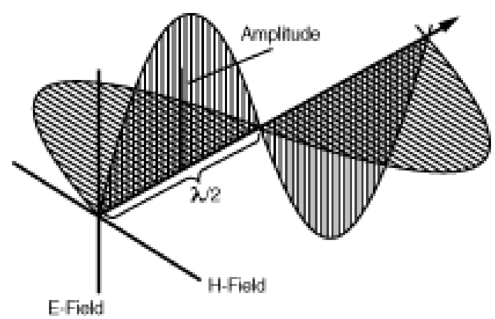




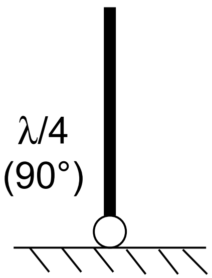
The **Magnetizing field** or H-plane lies at a right angle to the E-plane.

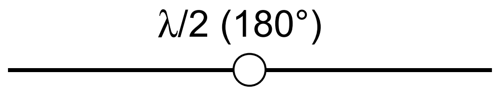
For a vertically polarized antenna, the H-plane usually coincides with the horizontal/ azimuth plane.

For a horizontally-polarized antenna, the H-plane usually coincides with the vertical/elevation plane.



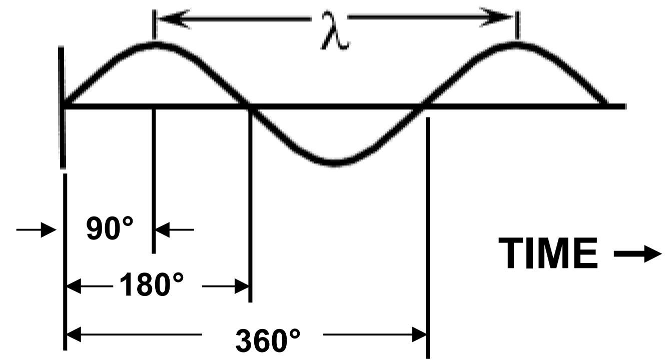
ANTENNA LENGTH





$$1 \text{ WL (meters)} = \frac{300}{F_{MHz}} = \text{Lambda } (\lambda)$$

Antenna Length is usually described as wavelength (WL) in meters or degrees:



Frequency (MHz)	Wavelength (Meters)	(Feet)
1.8	160	510
3.75	80/75	252
5.36	60	175
7.15	40	131
10.125	30	92.4
14.175	20	66
18.1	17	51.2
21.225	15	44
24.9	12	37.6
28.5	10	33
52	6	18

$$\frac{\textbf{360 deg}}{\textbf{deg}} = \frac{\textbf{Freq Length (ft)}}{\textbf{ft}}$$

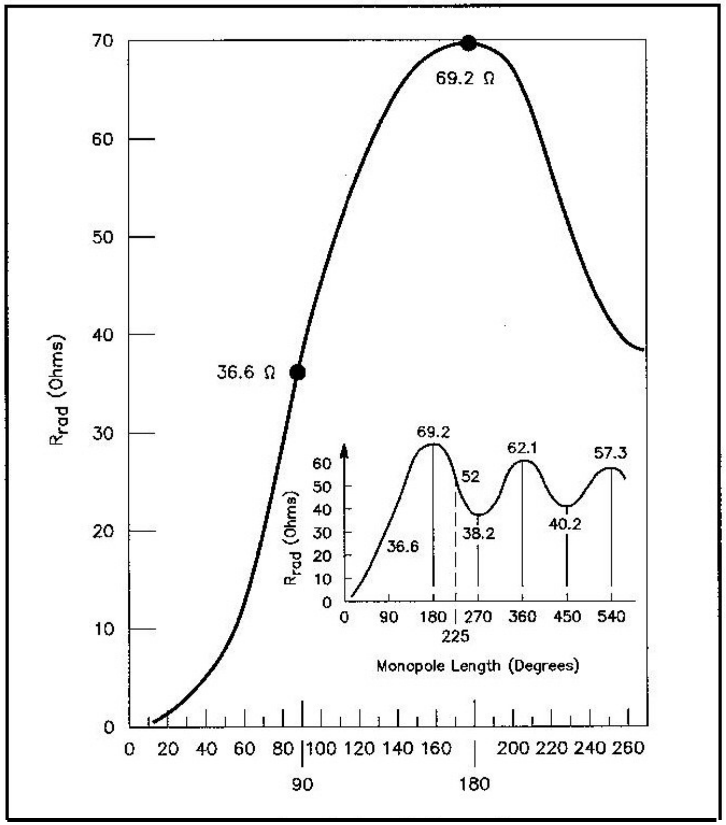
Example: 50 ft vertical used on 160 m

$$\frac{\textbf{360 deg}}{\textbf{deg}} = \frac{\textbf{510 ft}}{\textbf{50 ft}}$$

360 X 50 / 510 = 34.6 degrees

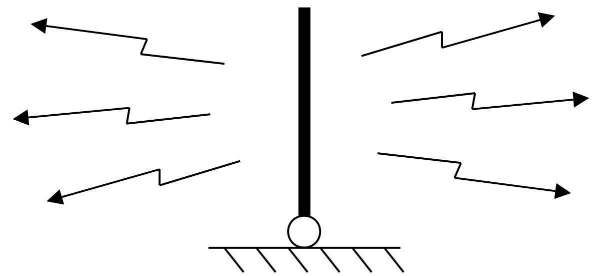
VERTICALS

Basic Vertical (Monopole) Radiation Resistance



Feedpoint Radiation Resistance vs Degrees (Double for Dipole)

Radiation Resistance (R_{rad}) is that portion of the antenna input resistance that radiates power.



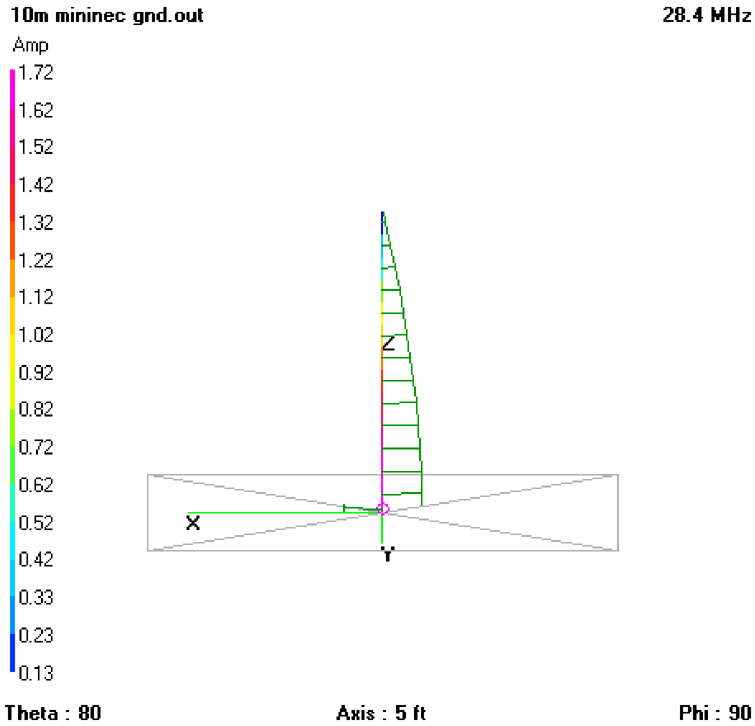
Radiation Resistance =
Power radiated / input current squared

The other portions are ground loss and antenna structure loss that dissipate power as heat.

Example: 160 m 50 ft vertical = 34.6 deg = 6 Ohms

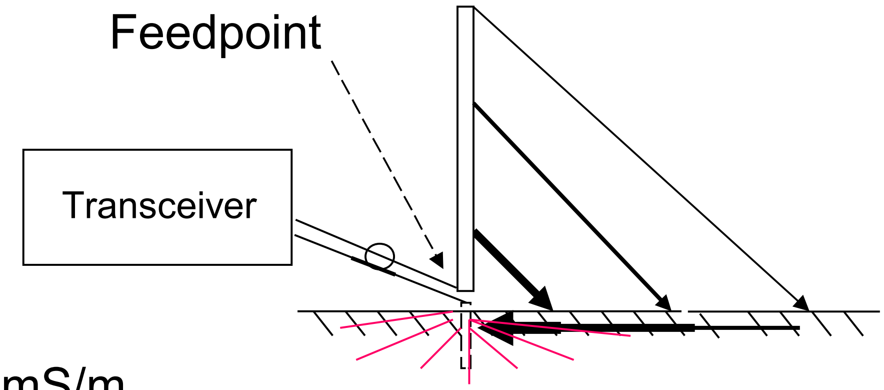
VERTICALS

Ground Losses (R_{gnd}) and Current Flow



The further up the element the less current flows (the voltage increases)

Thus, for less I^2R ground losses (R_{gnd}), it's Important have more return paths near the feedpoint



Soil – Ground Rod - Radials

North Texas soil conductivity is 30 mS/m
Poor soil conductivity is 10 mS / meter
Sea water conductivity is 5000 mS / meter
S = Siemens (MHOs outdated term)

VERTICALS
Efficiency and SWR

Feedpoint Resistance (R_{in}) = $R_{rad} + R_{gnd} + (R_L + R_s)$

Antenna Efficiency = $\frac{R_{rad}}{R_{in}}$ OR $\frac{R_{rad}}{R_{rad} + R_{gnd} + (R_L + R_s)}$

Examples: 50 ft 160 m vertical with 4/8/16 radials

$$\text{Eff} = \frac{6 \text{ Ohms}}{6 + 20 + 4 \text{ Ohms}} = \frac{6 \text{ Ohms}}{30 \text{ Ohms}} = 20\%$$

6 + 15 + 4 Ohms = 25 Ohms = 24%

6 + 10 + 4 Ohms = 20 Ohms = 30%

R_{in} – Feedpoint resistance at resonance ($X_C = X_L$ or $jX = 0$)

(measured with an MFJ)

R_{rad} – Radiation resistance

R_{gnd} – Ground resistance

R_L – Loading resistance

R_s – Structural resistance

SWR = $\frac{R_{in}}{\text{Coax } Z}$ or $\frac{\text{Coax } Z}{R_{in}}$ (use the larger number on top)

SWR = $\frac{\text{50-Ohm Dummy Load}}{\text{50-Ohm Coax}}$ = 1:1

SWR = $\frac{\text{50-Ohm Coax}}{\text{30 Ohms } R_{in}}$ = 1.66:1

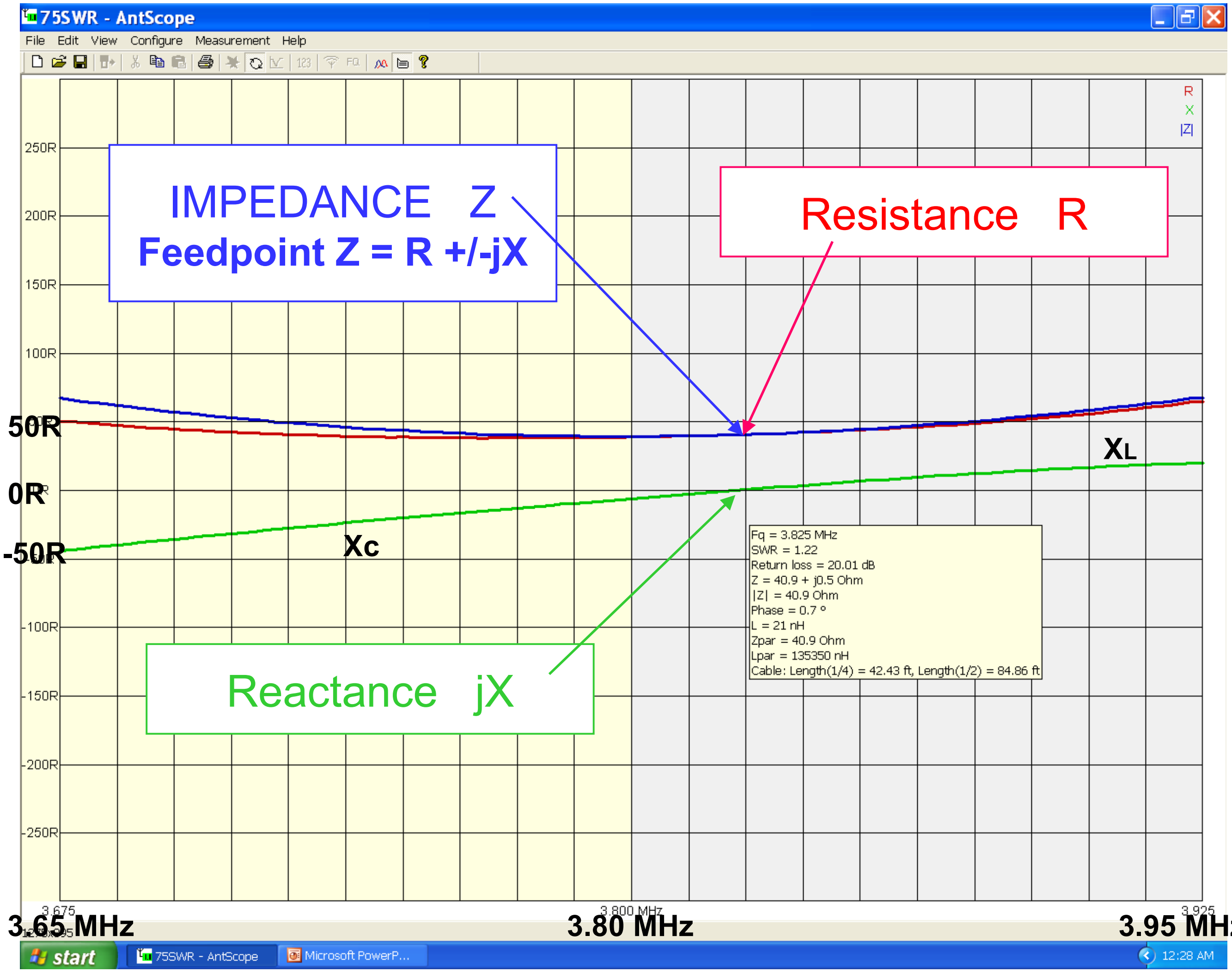
SWR = $\frac{\text{50-Ohm Coax}}{\text{25 Ohms } R_{in}}$ = 2:1

SWR = $\frac{\text{50-Ohm Coax}}{\text{20 Ohms } R_{in}}$ = 2.5:1

VERTICALS

Actual HyGain 18HT Vertical Impedance Data

MFJ 269 ANALYZER



41 (Rin) – 28 (Rrad) = 13 (Rgnd + Rs)   28 (Rrad)/ 41 (Rin) = 68% Efficiency

VERTICALS

Near Field is the area where the ultimate pattern is not fully formed, and E-H induction fields have a noticeable effect on forces we measure.

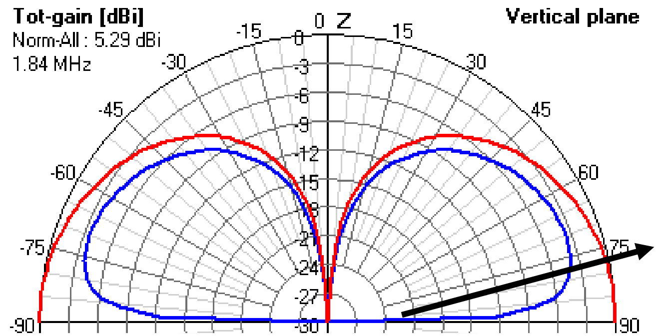
Frensel Zone is the area where the pattern is still being formed. It may or may not include E-H induction field areas.

Simple verticals have the Frensel zone extending out a few wavelengths.

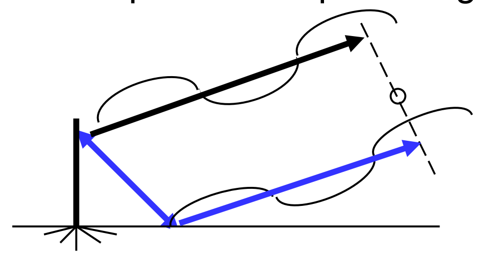
Physically large arrays almost always have large a Frensel zone.

Far Field is the area where any change in distance results in no noticeable change in pattern or impedance.

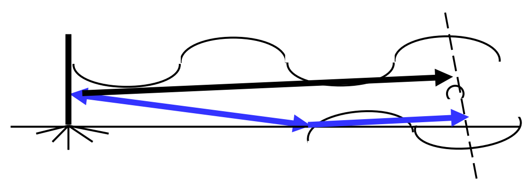
Radiation Pattern



Pseudo-Brewster Angle is typically at the -4 dB point from "perfect" ground



Signal reflection at an in-phase point (Augmentation)



Signal reflection at an out-of-phase point (Cancellation)

Pseudo-Brewster Angle (PBA): varies with the ground conductivity and dielectric constant.

The vertically-polarized reflected wave (from a flat earth or water surface) is 90 degrees out of phase and minimum amplitude with respect to the direct wave.

Above this angle, the reflected signal is in-phase with the direct signal and augments it.

Below this angle, the reflected wave is between 90 to 180 degrees out-of -phase with the direct wave and reduces it.

PBA is that angle at which the direct wave reduces it.

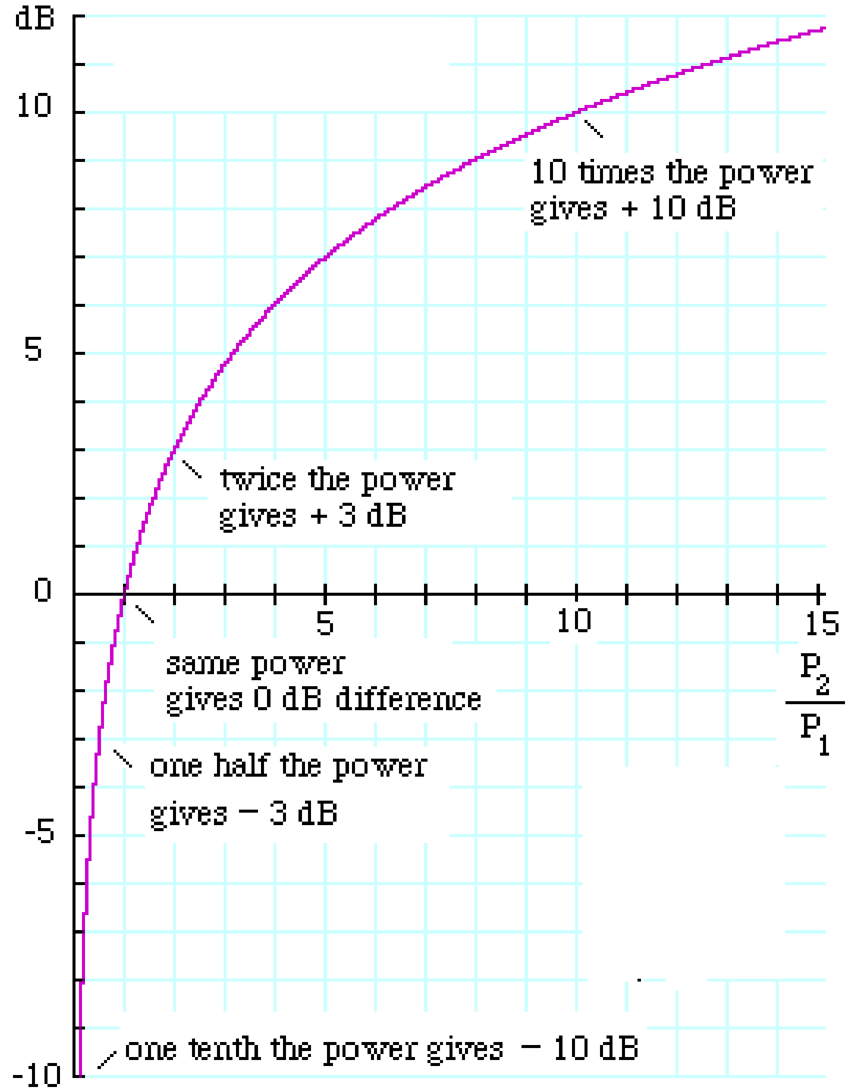
-Courtesy of Tom McDermott –N5EG

DECIBELS

The **decibel** (**dB**) is a logarithmic unit that indicates the **ratio** of a physical quantity (usually power) relative to a specified reference level

The **difference in decibels** between two power levels is defined to be 10 log (P2/P1) dB where the log is to base 10

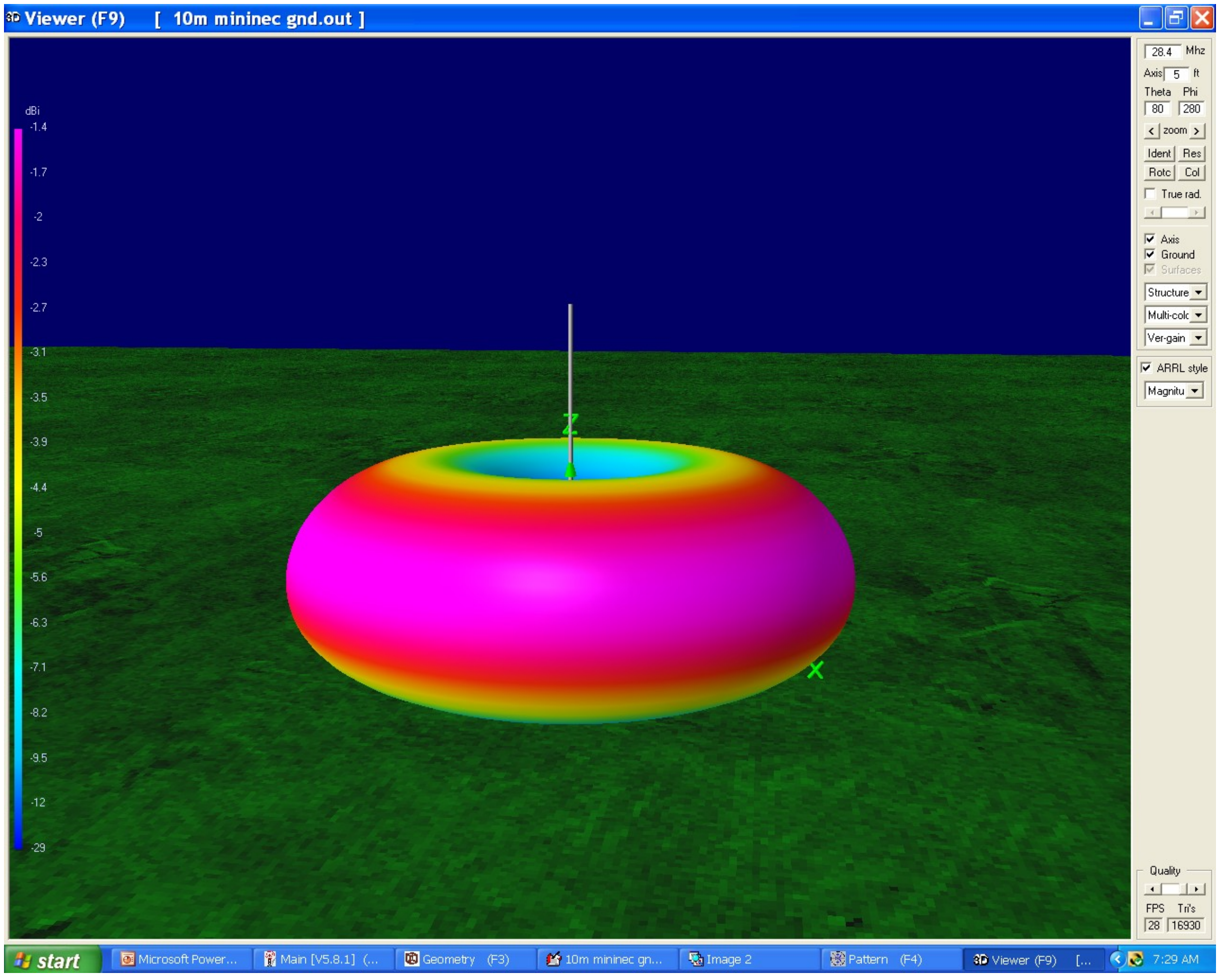
Example: 100 W transmitter driving a yagi antenna with 6 dB gain is equal to a dipole with 400 W drive.



VERTICALS

Basic Vertical (Monopole) Radiation Pattern

They say that verticals radiate equally poor in all directions



Not so fast.... Maybe so on 20 through 10 meters

But for DXing,

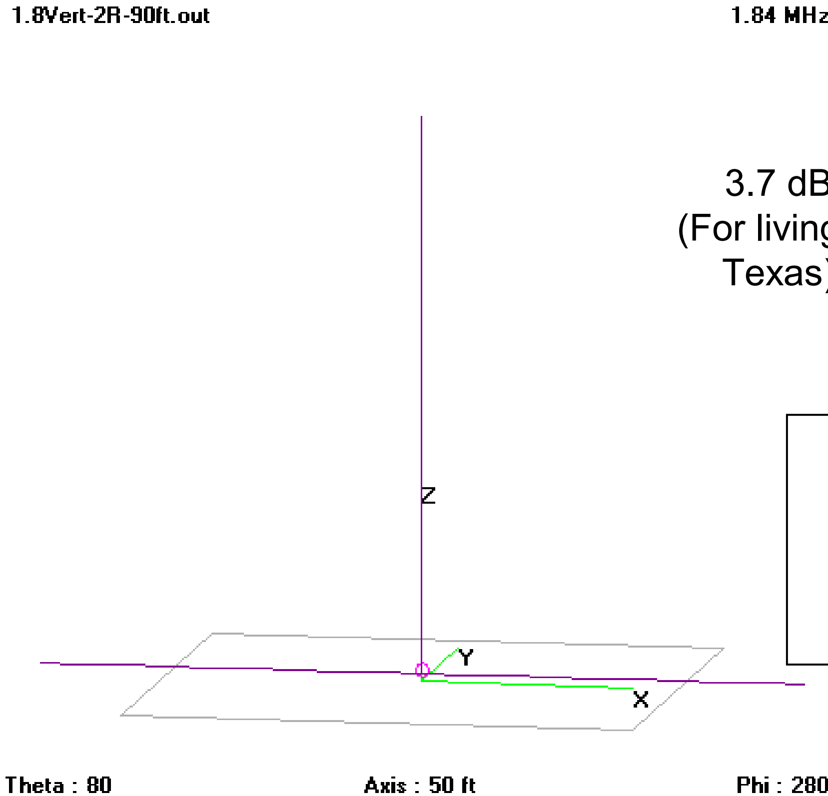
160 through 40 meters a vertical can do a good job compared to a low dipole -since it's more difficult to get a dipole up at a good height.

Let's analyze this

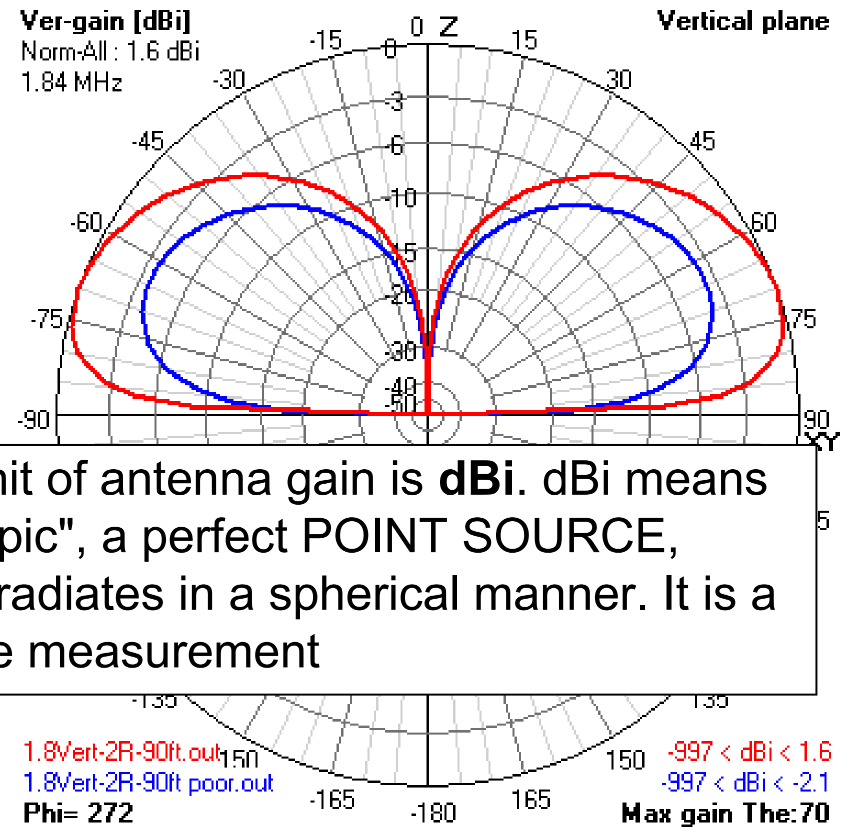
VERTICALS

160 m Vertical with two 90 ft radials

Comparison between poor ground and good ground



3.7 dB
(For living in Texas)

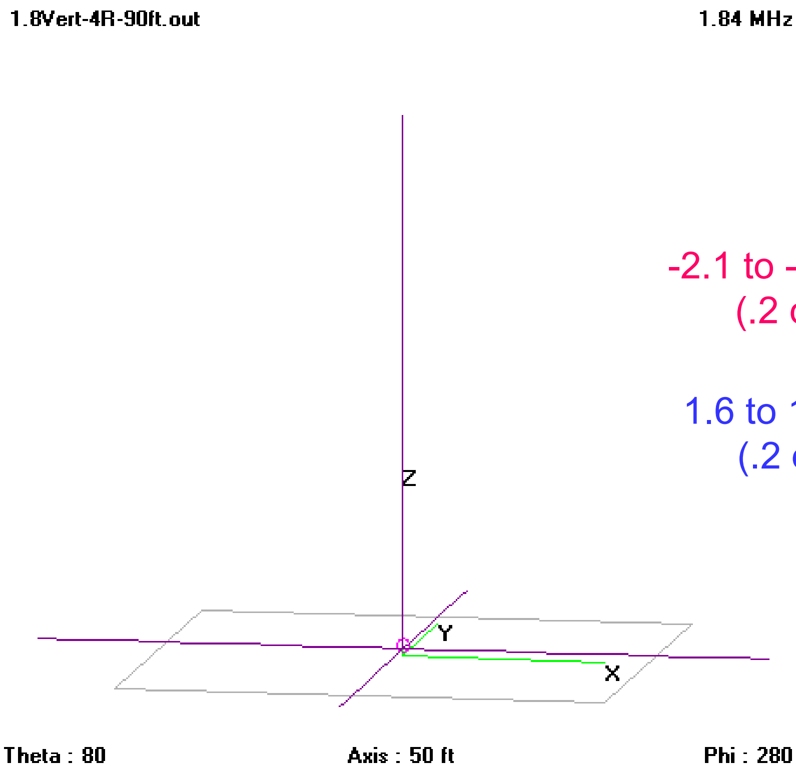


The unit of antenna gain is **dBi**. dBi means "Isotropic", a perfect POINT SOURCE, which radiates in a spherical manner. It is a relative measurement

VERTICALS

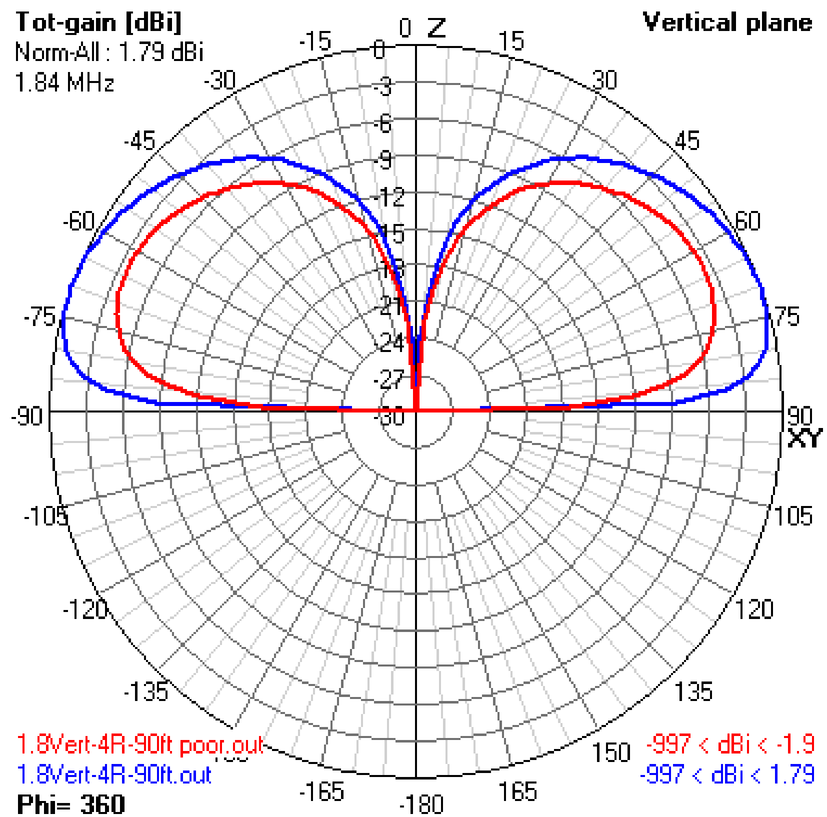
160 m Vertical with four 90 ft radials

Comparison between poor ground and good ground



-2.1 to -1.9 dBi
(.2 dB)

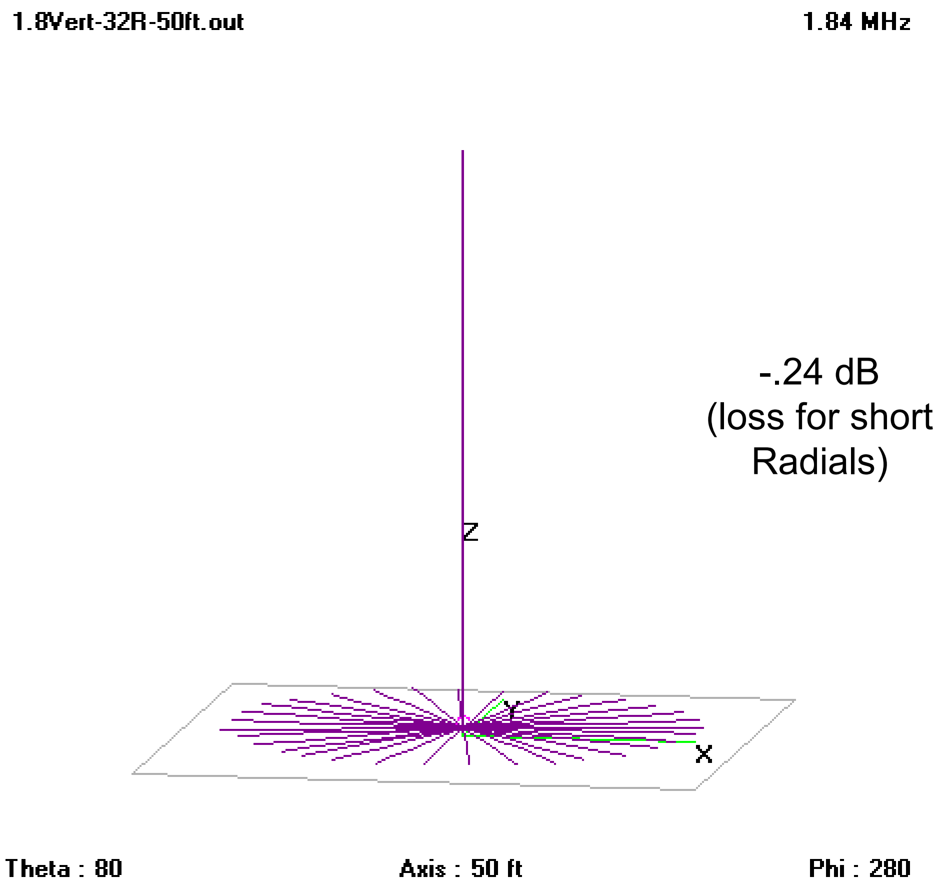
1.6 to 1.8 dBi
(.2 dB)



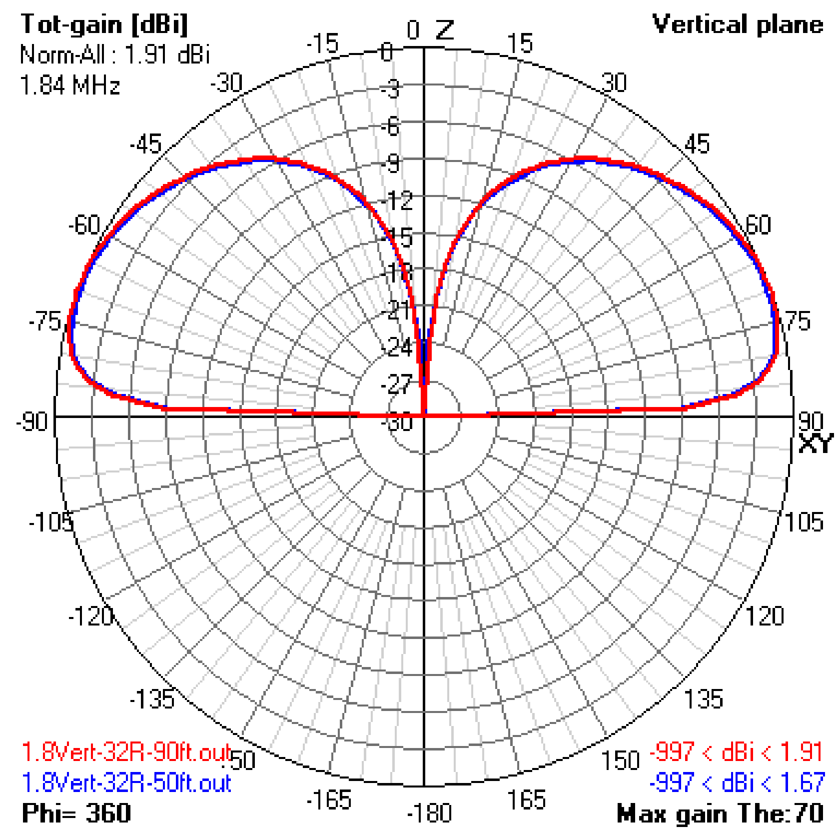
VERTICALS

160 m Vertical with thirty-two radials

Comparison between 50 ft and 90 ft radials (Good Ground)



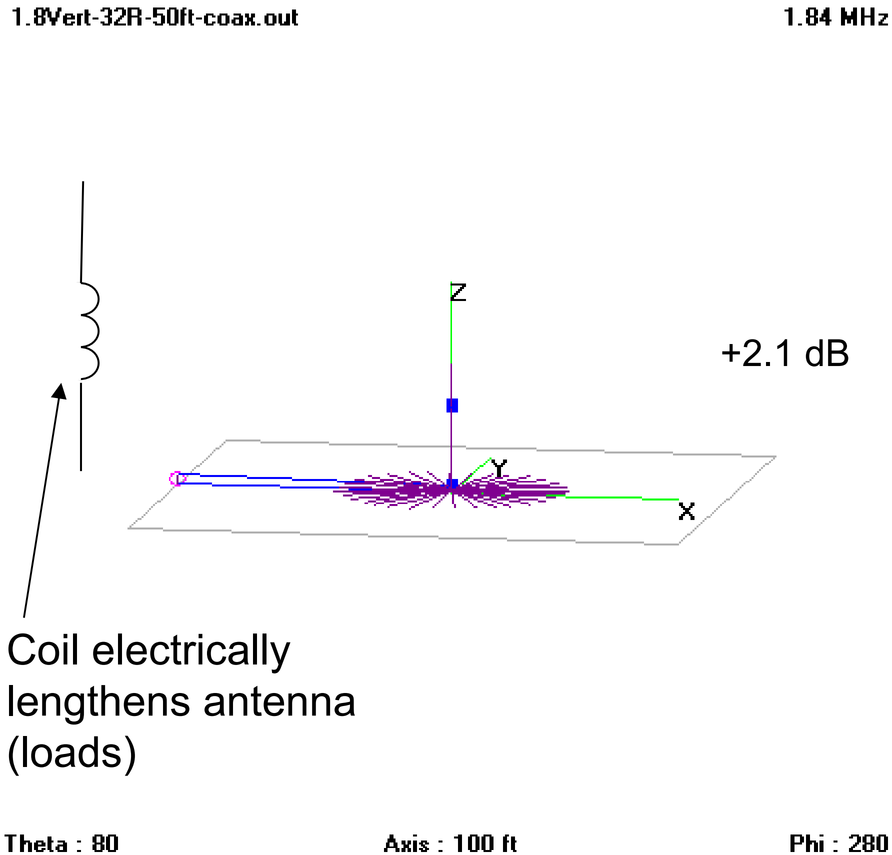
-.24 dB
(loss for short
Radials)



VERTICALS

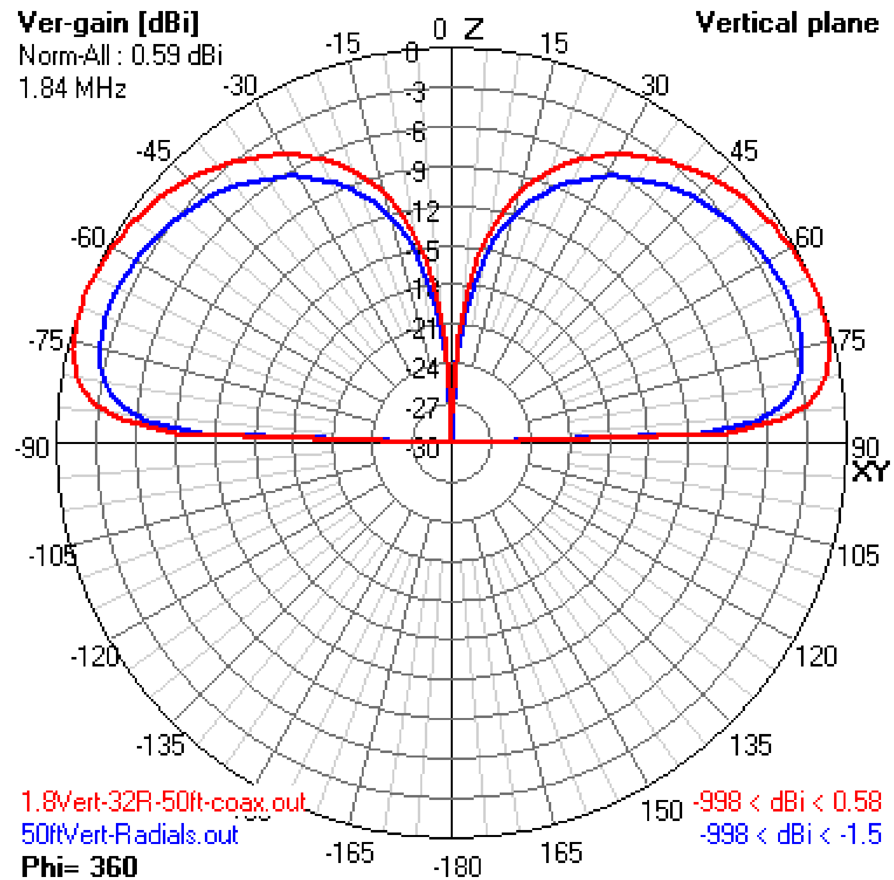
50 ft Shortened 160 m Verticals with 32 Radials

Comparison between Inductively (coil) baseloaded and centerloaded



+2.1 dB

Coil electrically lengthens antenna (loads)

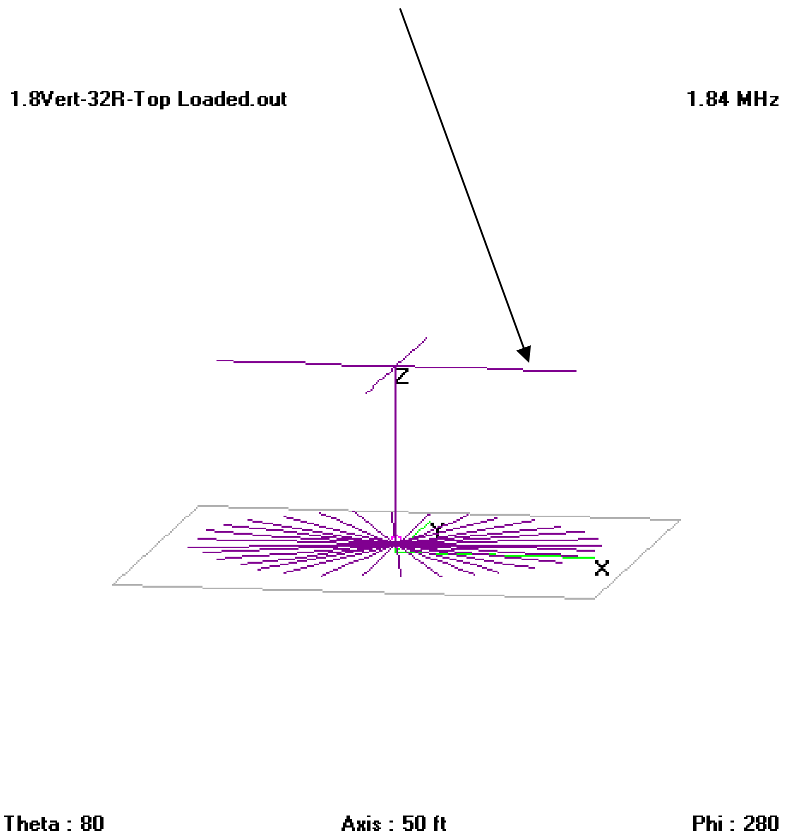


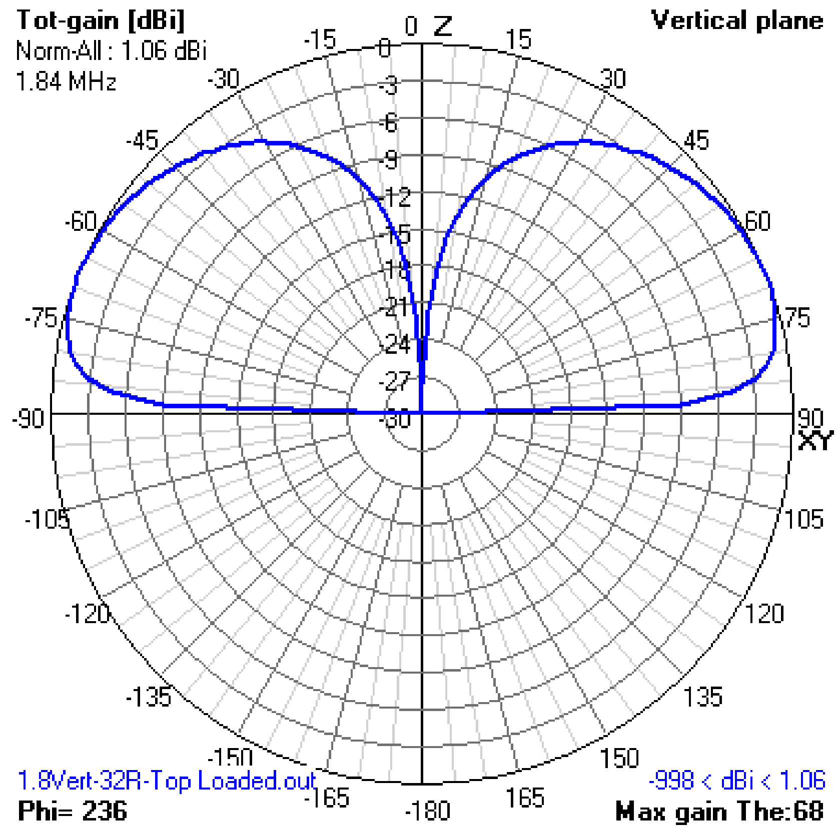
VERTICALS

50 ft Shortened 160 m Verticals with 32 Radials

Capacitive (Top Hat) Loaded

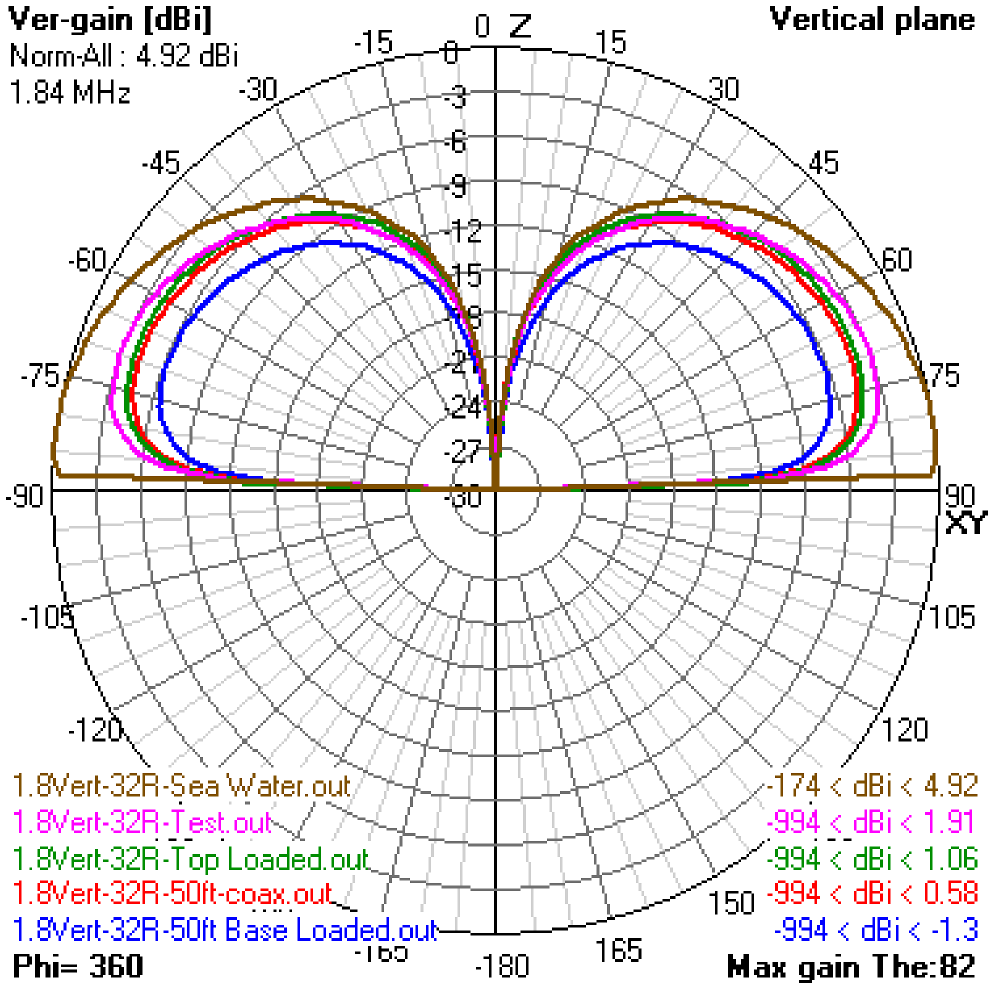
Capacitive loading
Electrically lengthens
antenna





VERTICALS

Summary Between 50 ft Shortened 160 m Verticals and Full-Size Vertical with 32 radials



	Rad Eff	Gain	Loading
Base Loaded	23.3%	-1.5 dBi	40.7 W
Center Loaded	37.3%	0.58 dBi	24 W
Top Loaded	41.8%	1.06 dBi	---
Full Size	45.6%	1.67 dBi	---
FS Sea Water	95.1%	4.92 dBi	---

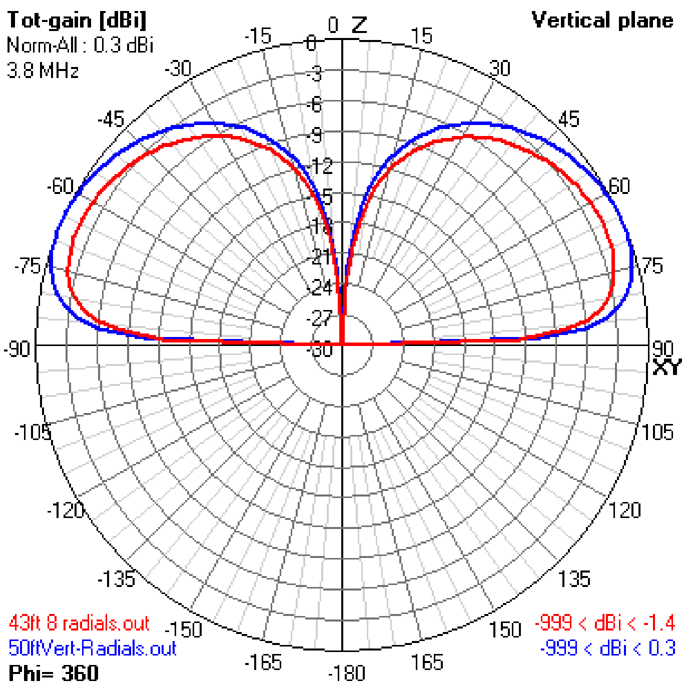
VERTICALS

Comparison between 43 ft and 50 ft matched base-loaded verticals at 3.8 MHz

43 ft -coil loss 6.2 W and 8 radials is 22.9% efficiency

50 ft -3.7 W and 16 radials is 33.9% efficiency

+2 dB



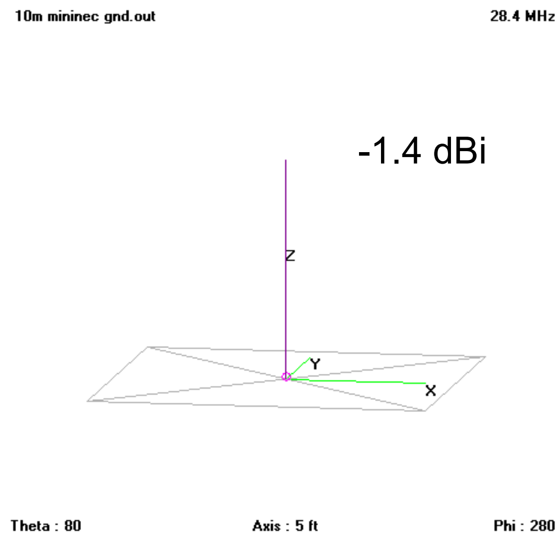
43 ft Vertical

Shown with base loading coil for 160 m and RF choke

VERTICALS

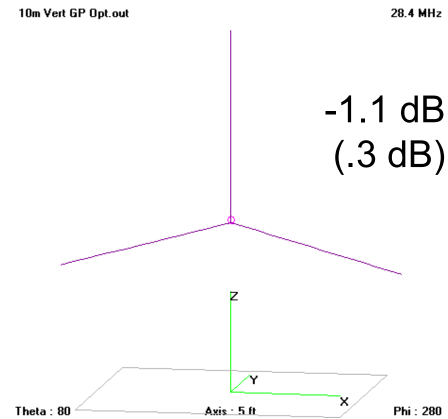
Comparison Between Three 10 m Verticals (Mininec Ground)

1/4 Wave Vertical



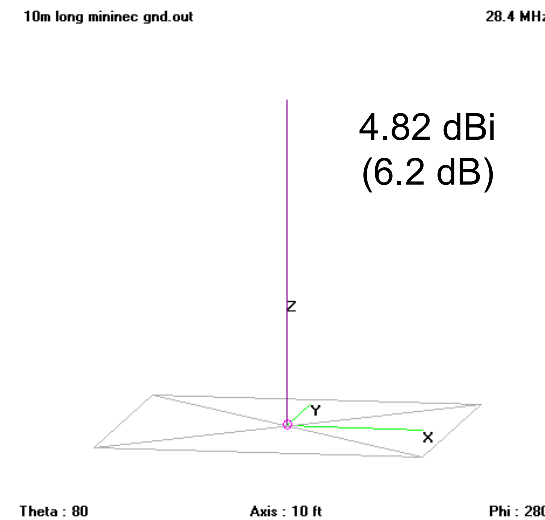
-1.4 dBi

¼ Wave Groundplane
8 ft Above Ground

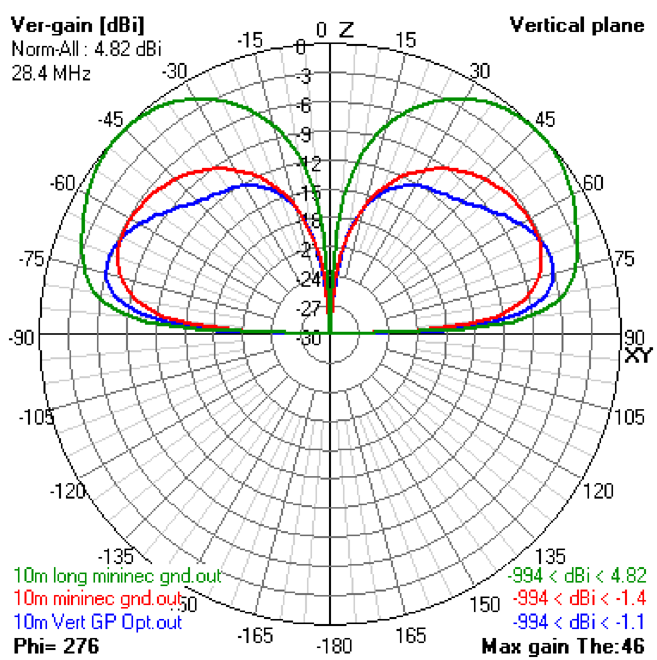


-1.1 dBi
(.3 dB)

¾ Wave Vertical

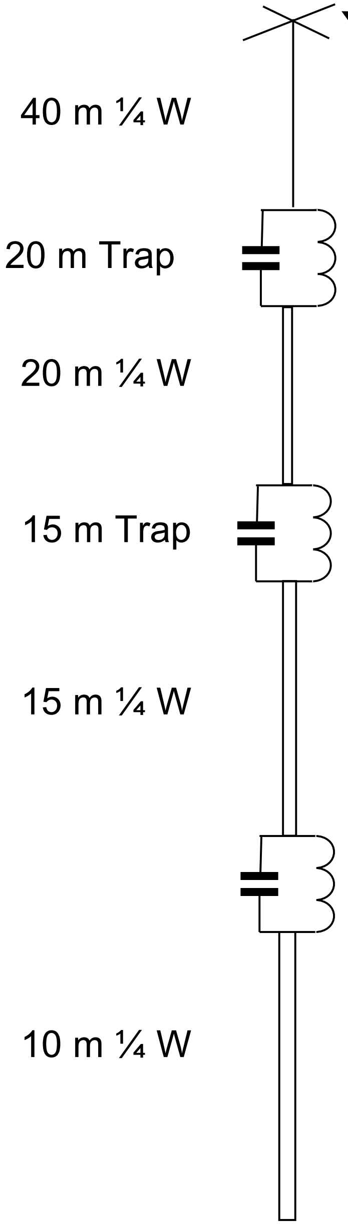


4.82 dBi
(6.2 dB)

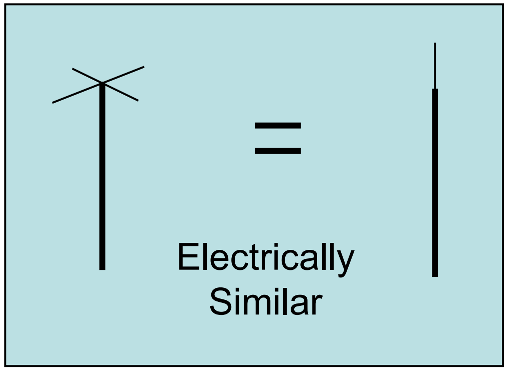


VERTICALS

L-C Trapped Multiband

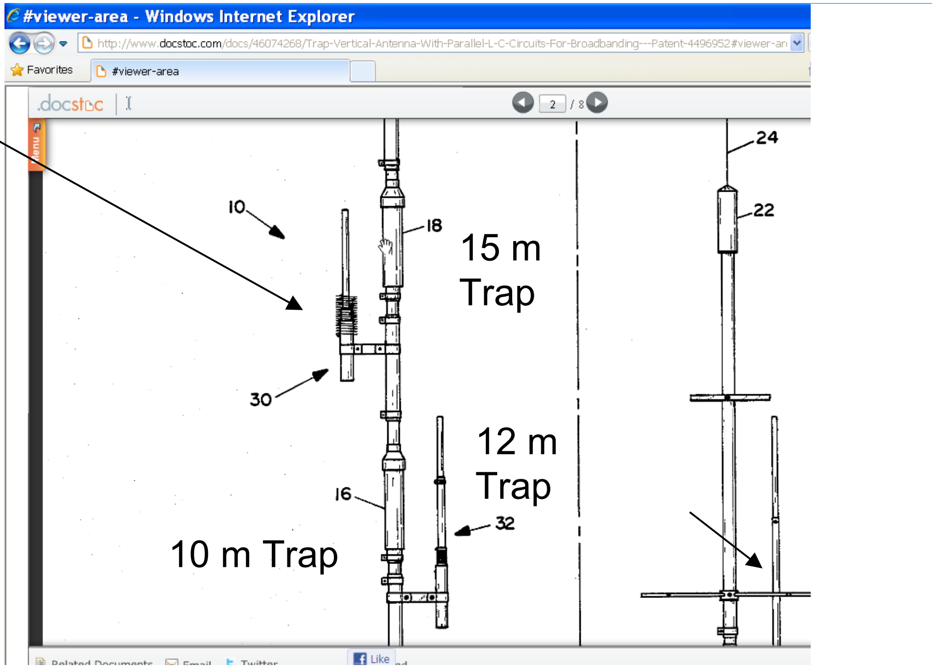


Capacity Loading (top hat)
-Electrically lengthens element



Add-on trap kits
Fixed coil with sliding rod
Patent No. 4 496 953 (Butternut)

17 m Trap

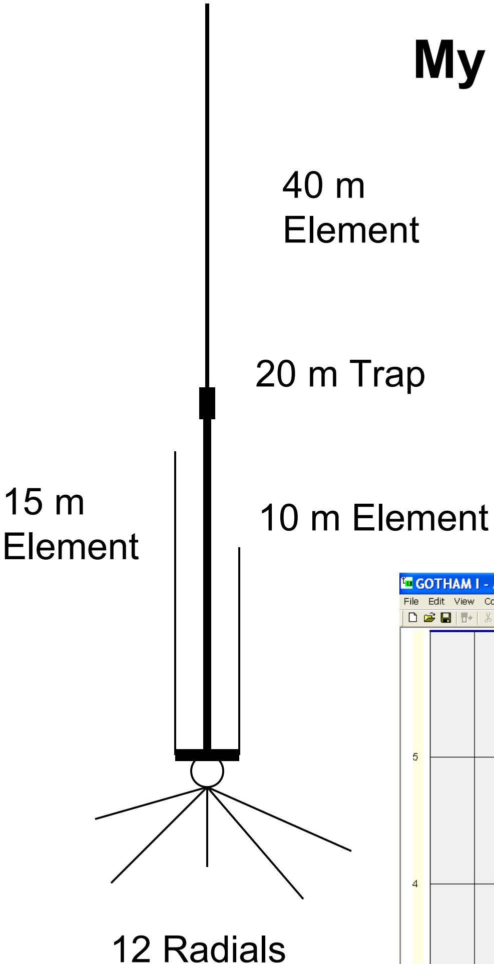


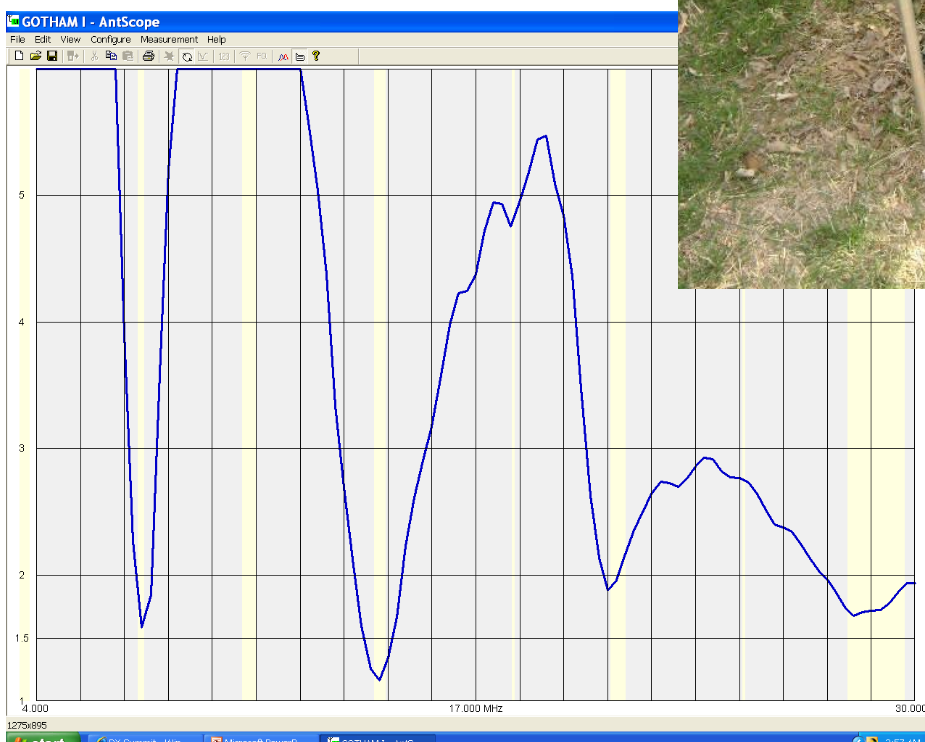
10 m Trap
-An L-C resonant circuit that acts as a Hi-Z point to 10 m

Adds inductive loading to the next bands

VERTICALS

My 40/20/15/10 m 4-Band 29 ft Homebrew Vertical Parallel Elements



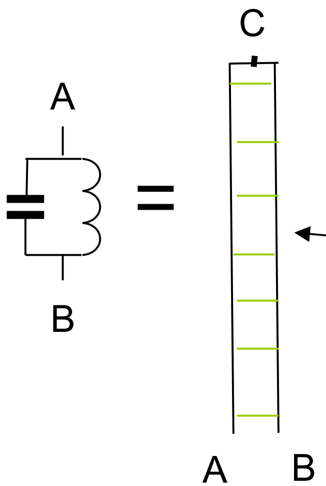


Separated for minimum coupling and interaction

VERTICALS

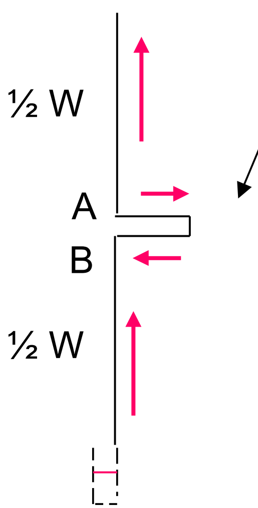
¼ W Decoupling Stub Multiband

Patent No. 2 535 298 –W J Lattin (1950)

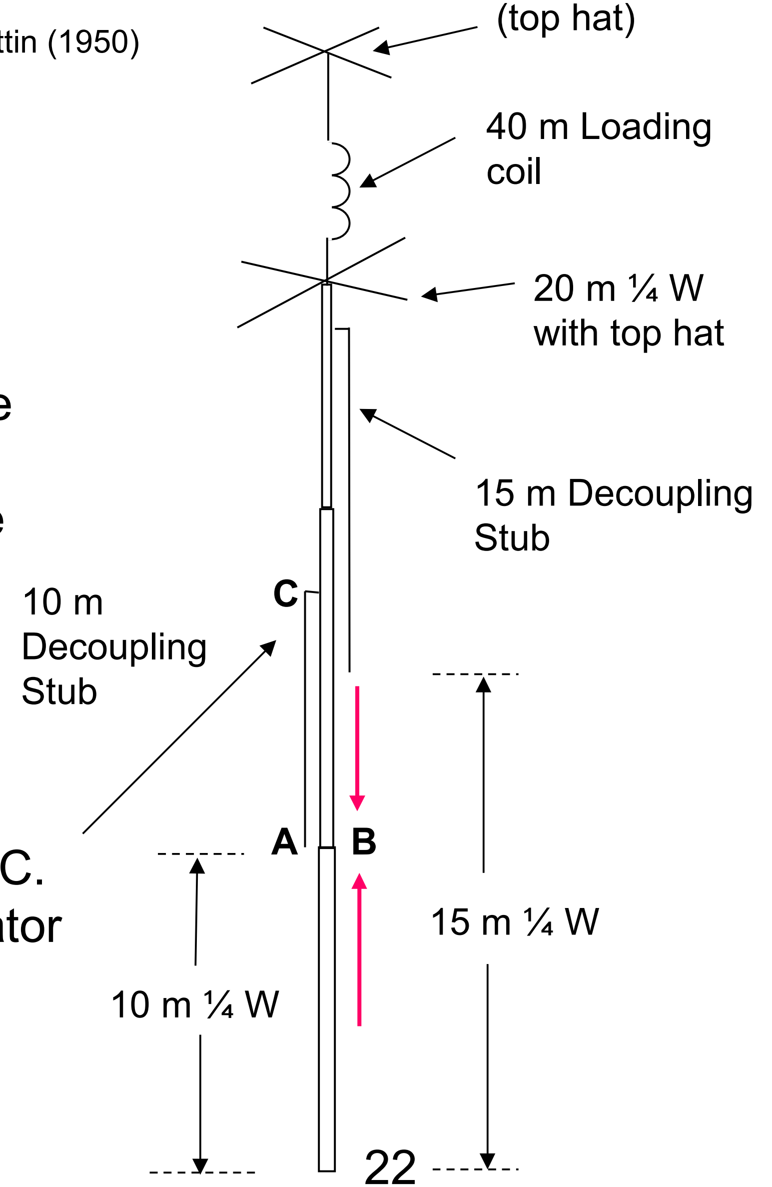


A ¼ wavelength trans-mission line X velocity factor is a resonant circuit which creates a phase shift at which the open end decouples that frequency from the main element

VHF/UHF Collinear (J-Pole Match)



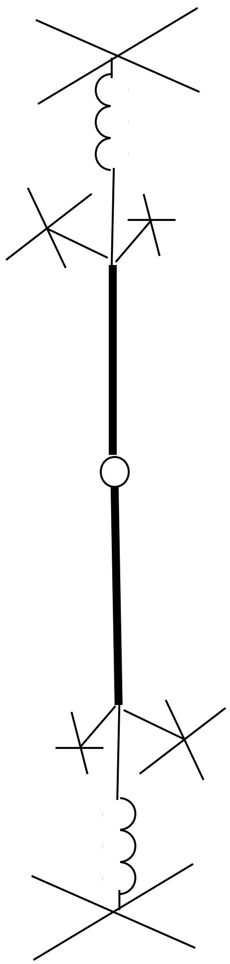
A different connection is possible -that is A to C. This results in an insulator action or decoupling



VERTICALS

Ground Independent Multiband Antennas

Electrical
Equivalent



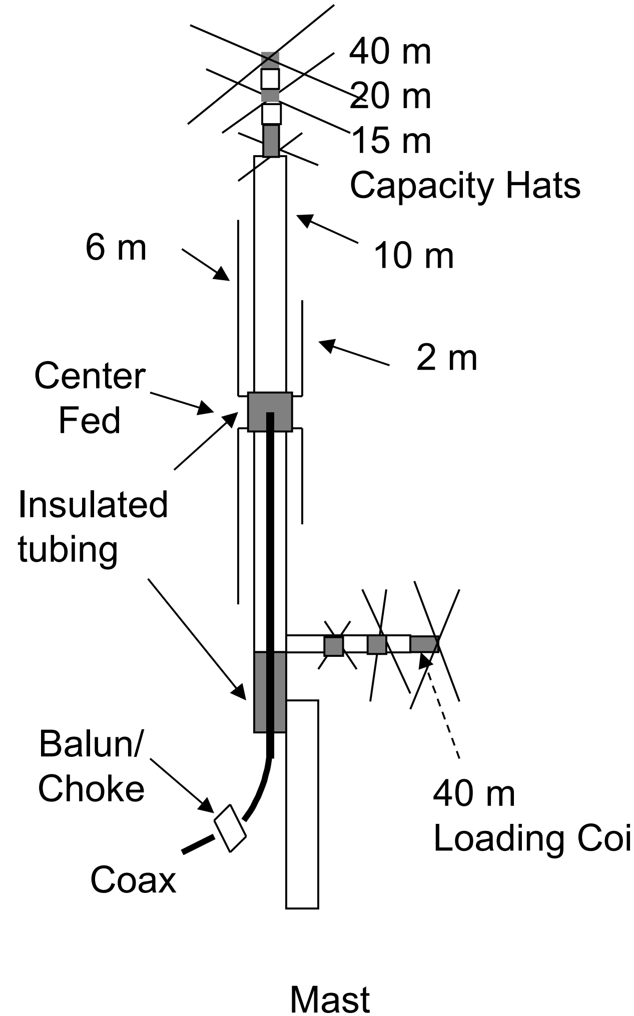
Vertically Polarized Loaded Dipole

Remember Hustler HF Mobile antennas?

This is basically what this design is
-only mechanically mounted on a mast

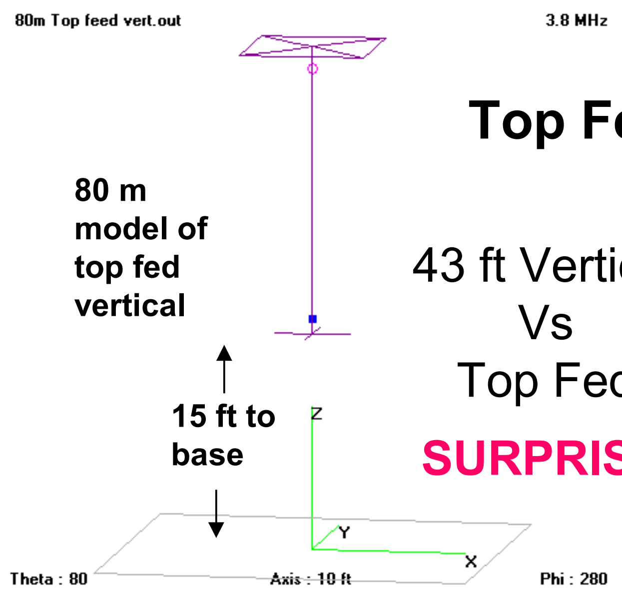
Just put to two of them back-to-back
and use three resonators and there
you have it

-Narrow bandwidth and low efficiency
on 20 and 40 meters



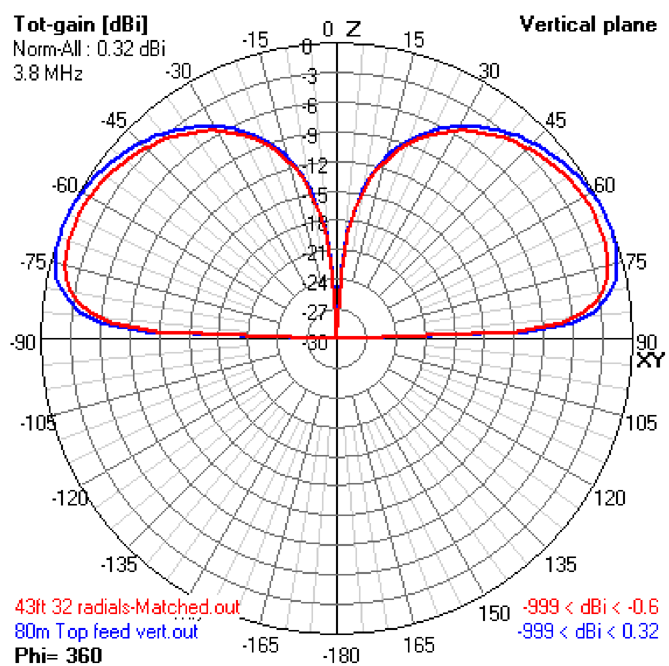
VERTICALS

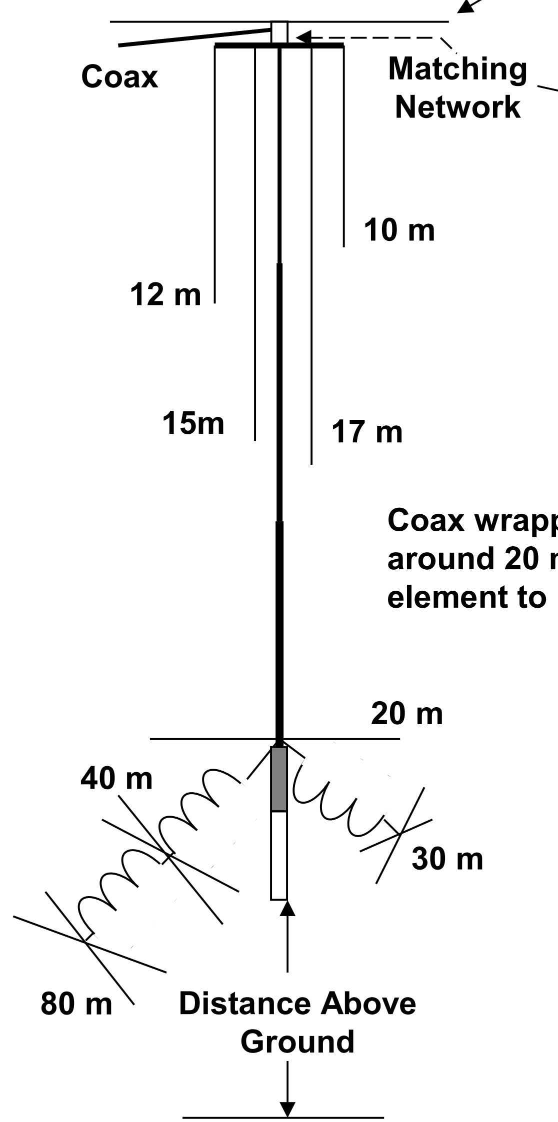
Top Fed Antennas -No Radials

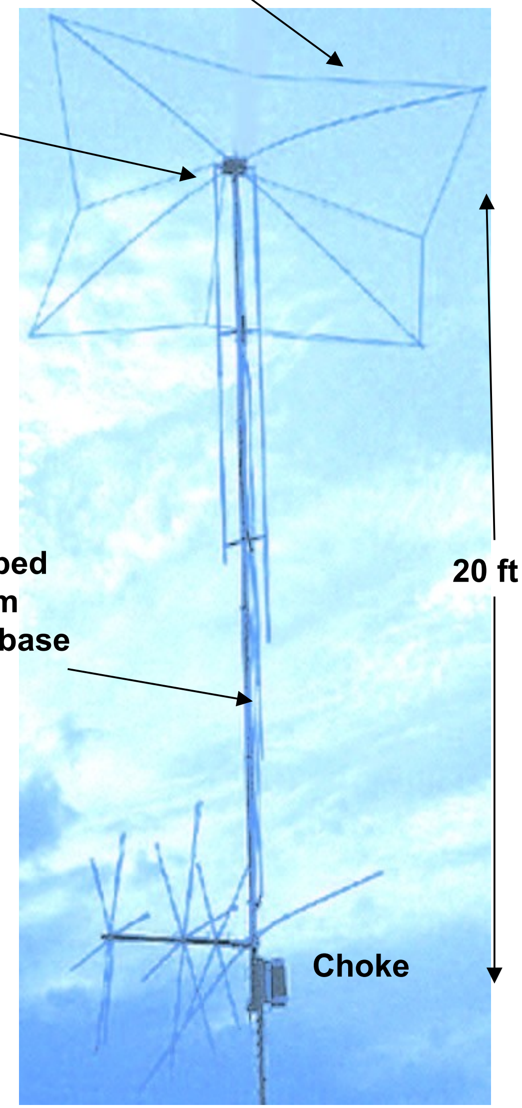


43 ft Vertical
Vs
Top Fed

SURPRISE!





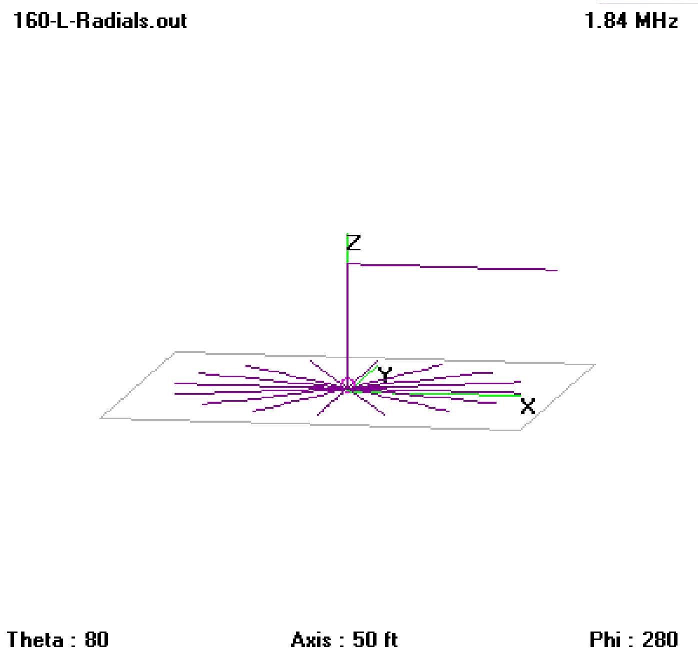


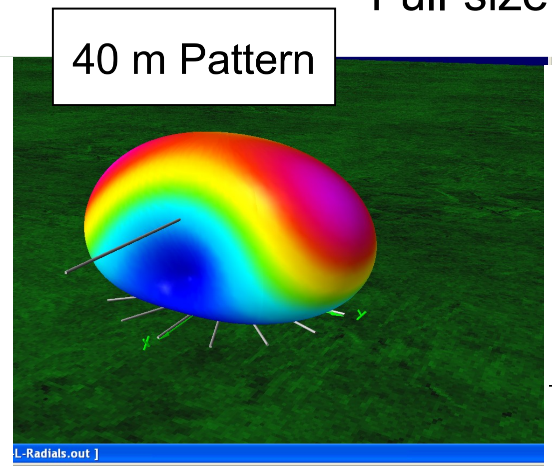
INVERTED-Ls and LONG WIRES

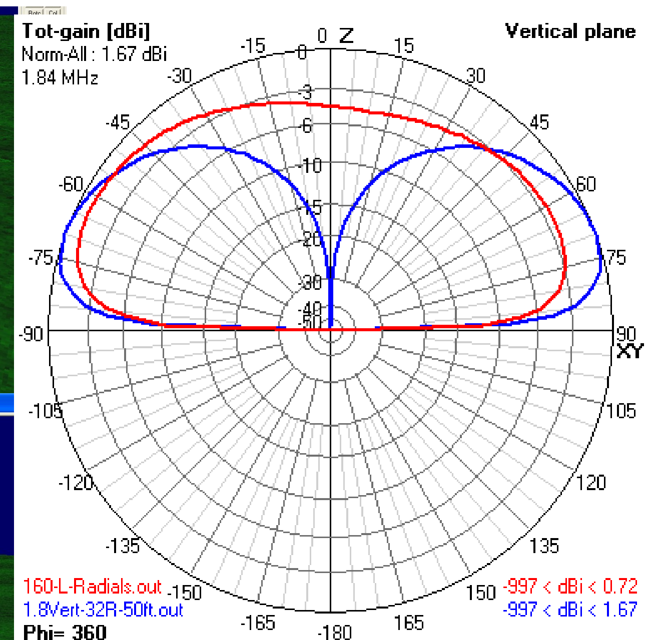
Similar to a Vertical –Have good efficiency due to long length -Require similar matching –a remote tuner can be used

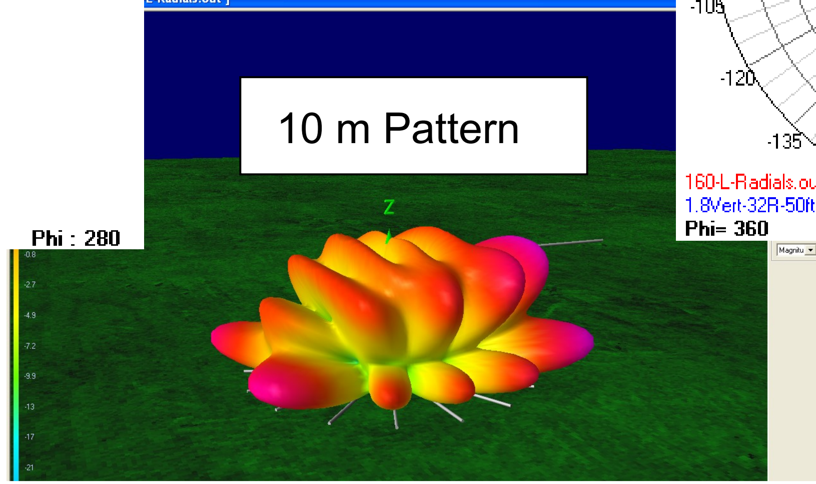
37 ft high X 90 ft long

Full-size vertical Vs Inv-L comparison



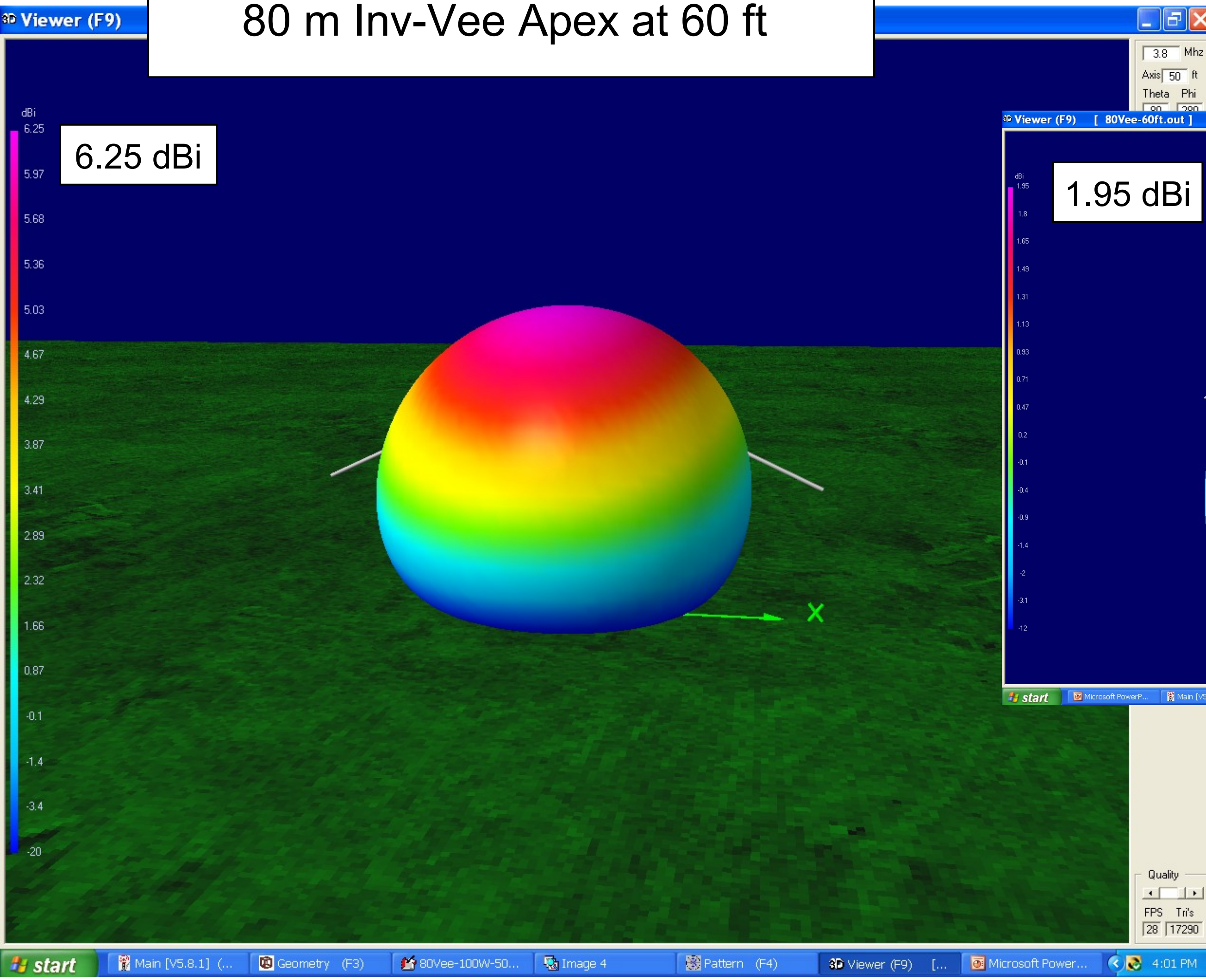


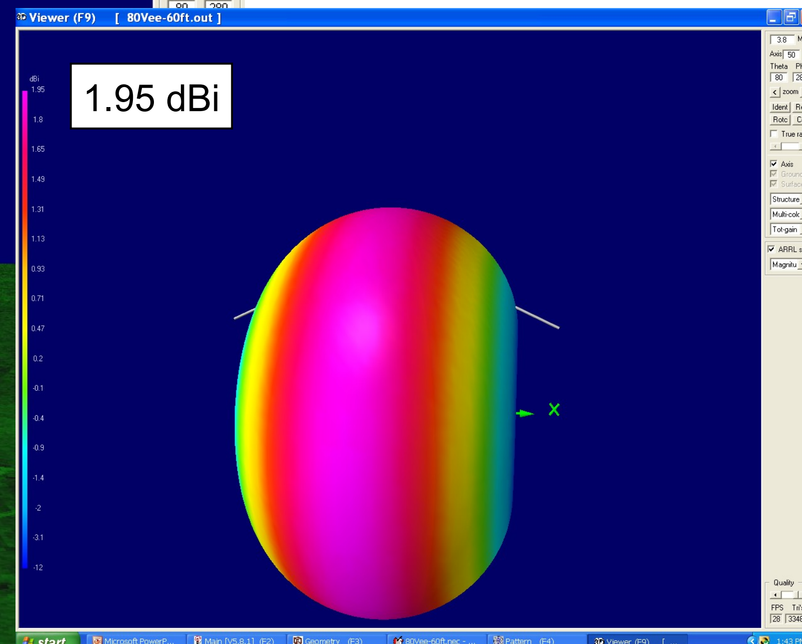




DIPOLES

80 m Inv-Vee Apex at 60 ft

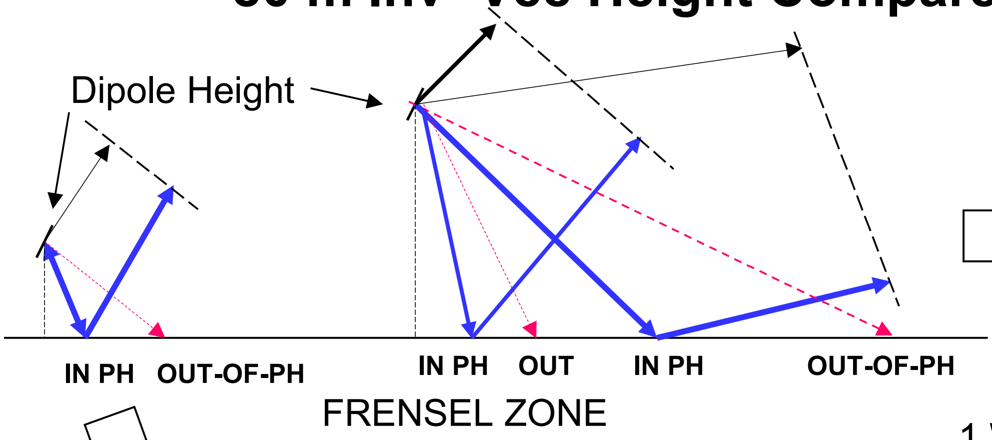




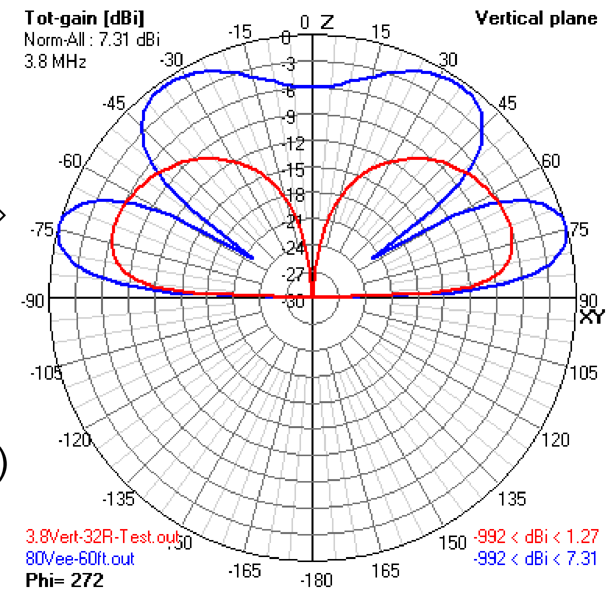
Free Space

DIPOLES

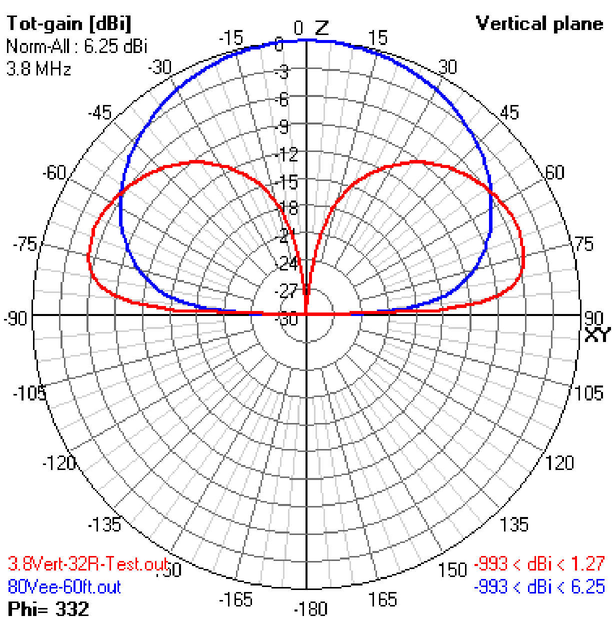
80 m Inv -Vee Height Compared to Full-Sized Vertical



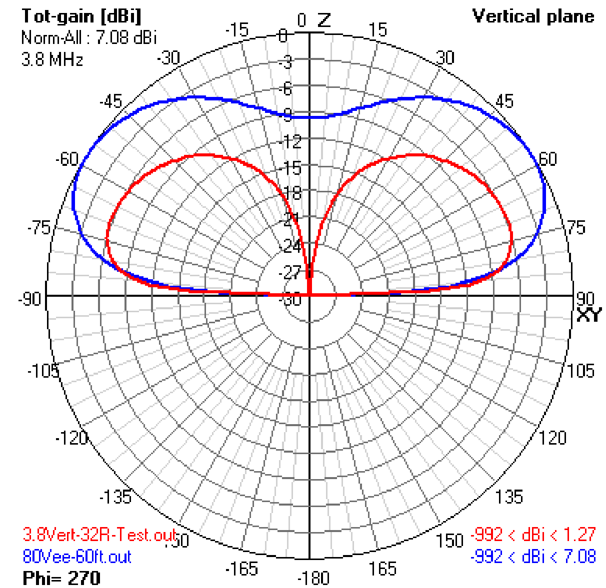
Note: For illustration purposes only



1 WL High
(240 ft Apex)



1/4 WL High
(60 ft Apex)



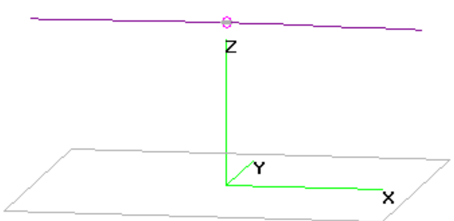
1/2 WL High
(120 ft Apex)

DIPOLES

½-Wavelength Dipole Vs Inv-Vee

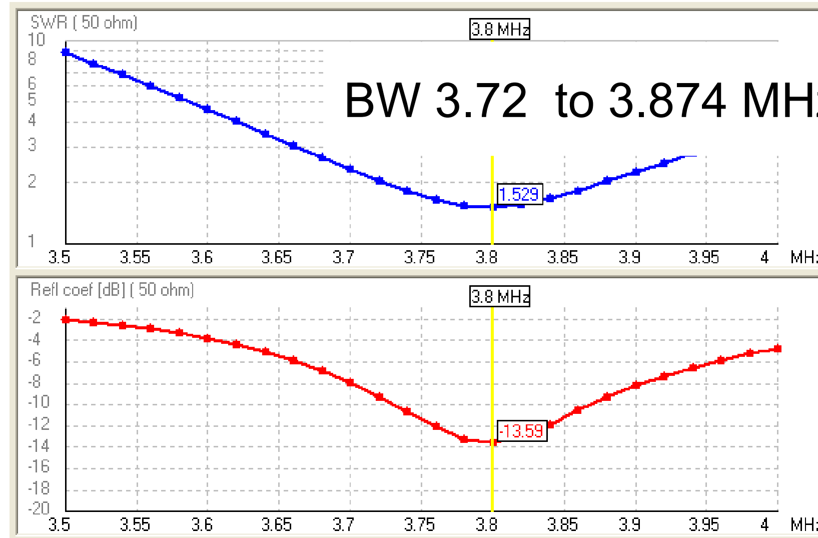
80dipole.out 3.8 MHz

80 m Dipole



Theta : 80 Axis : 50 ft Phi : 280

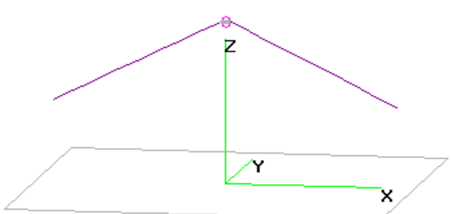
Z = 76 -j2.5
Eff = 84.7%
Fr = 3.8 MHz



BW 3.72 to 3.874 MHz

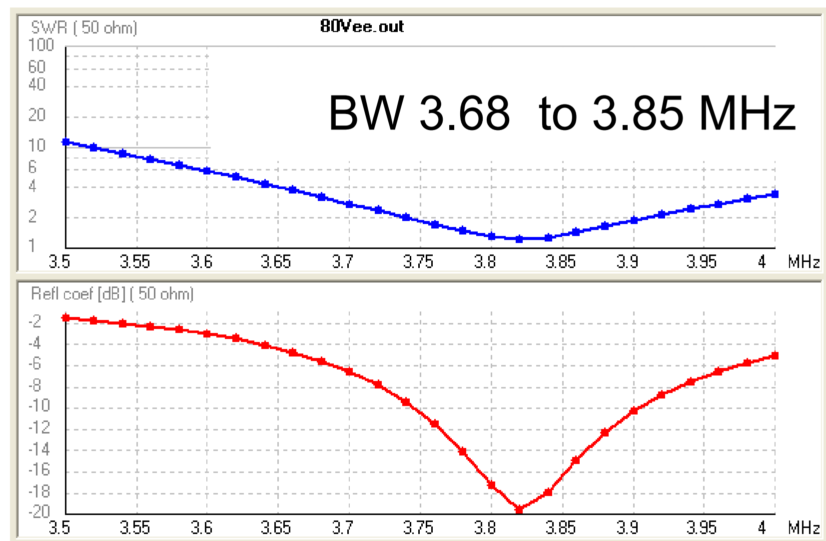
80Vee.out 3.8 MHz

80 m Inv-V



Theta : 80 Axis : 50 ft Phi : 280

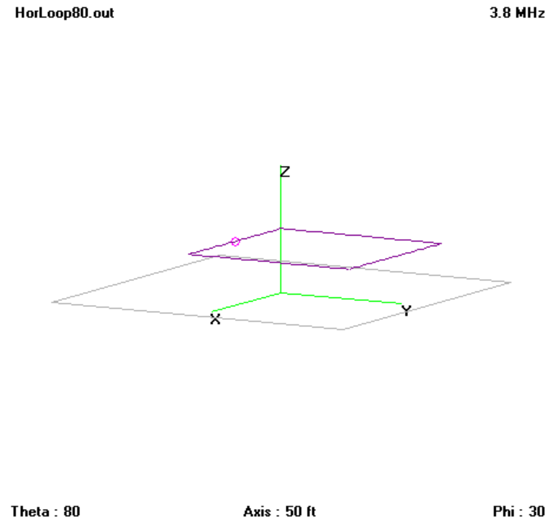
Z = 64 +j0.5
Eff = 76%
Fr = 3.77 MHz



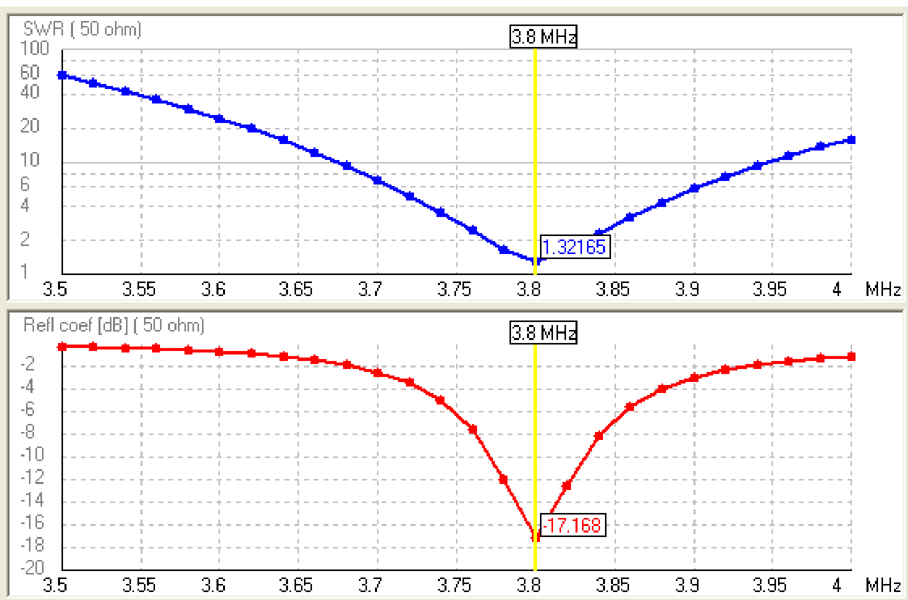
BW 3.68 to 3.85 MHz

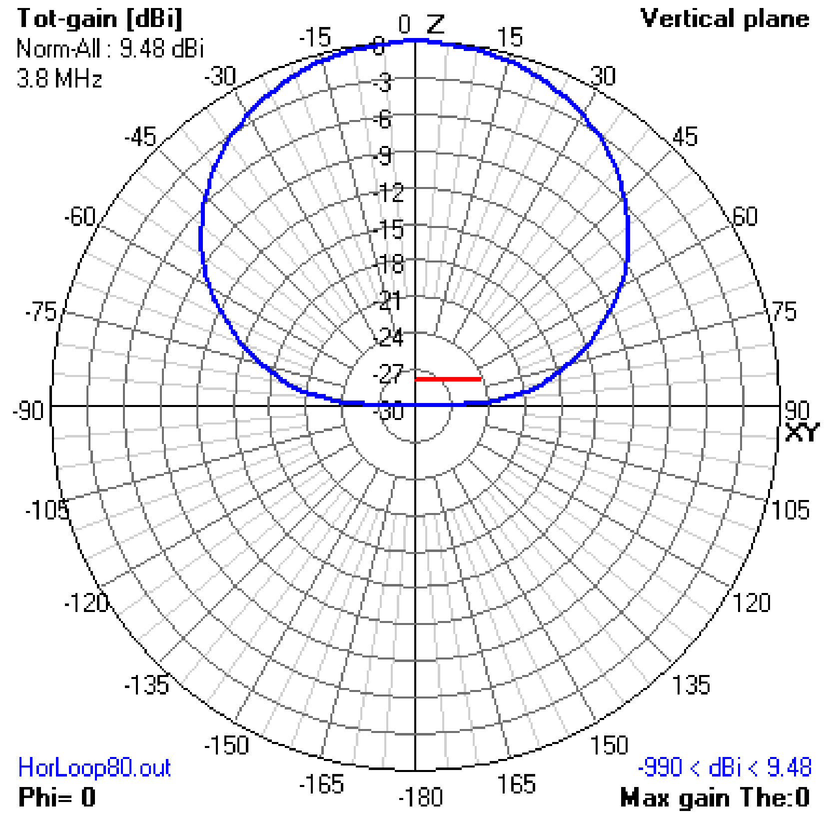
LOOPS

66 ft X 66 ft X 25 ft High 80 m Horizontal Loop Antenna



Z = 76 +j4
Eff = 54.9%
Fres = 3.8 MHz

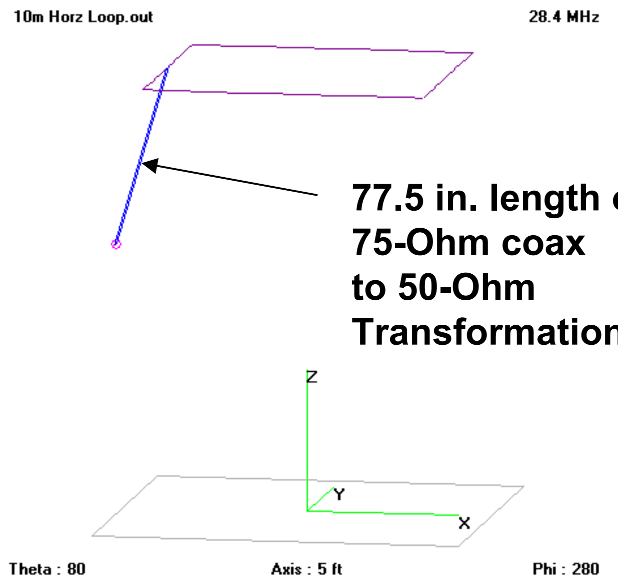




Near Vertical Incidence Skywave (NVIS)

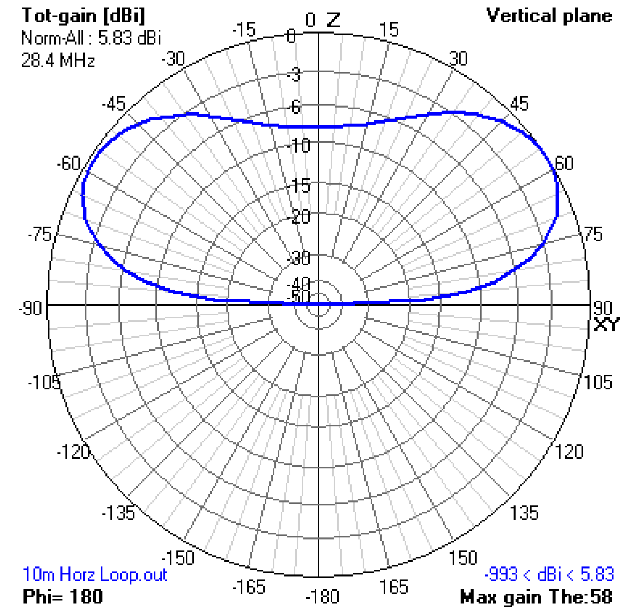
LOOPS

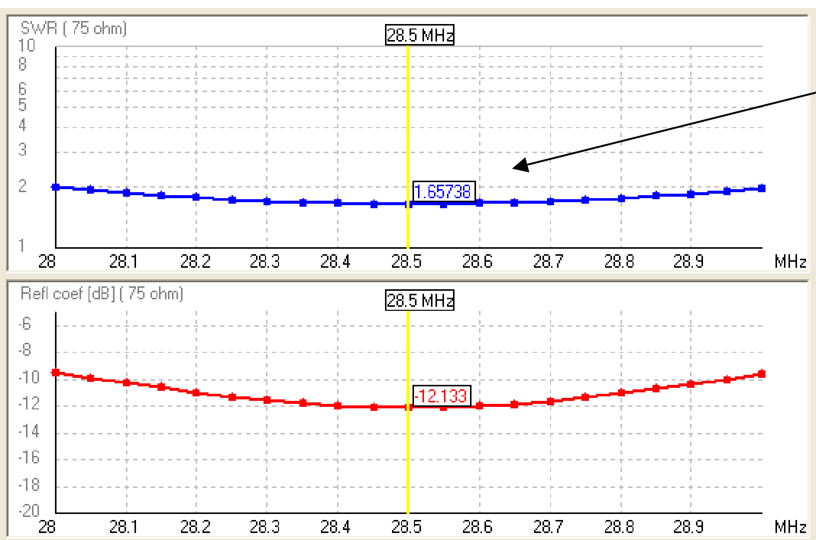
Roof Top 10 m Horizontal Loop Antenna



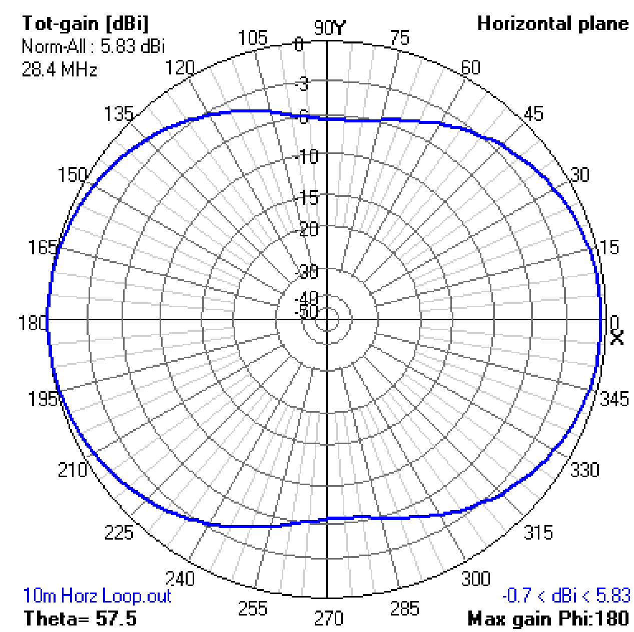
77.5 in. length of
75-Ohm coax
to 50-Ohm
Transformation

Z = 76 -j2.5
Eff = 84.7%
Fr = 28.5 MHz





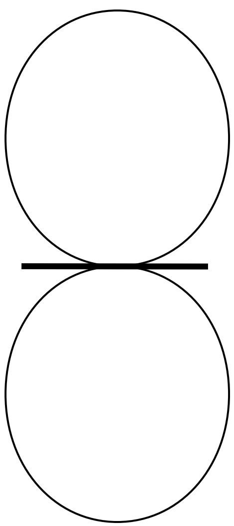
Direct feed
75-Ohm coax
SWR curve

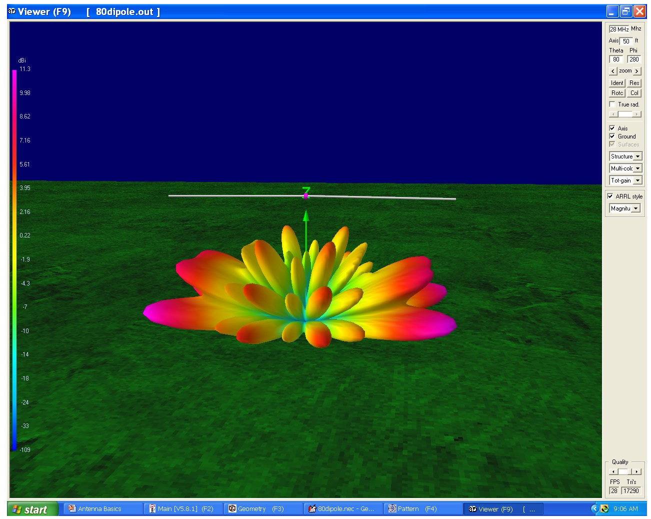


MULTIBAND

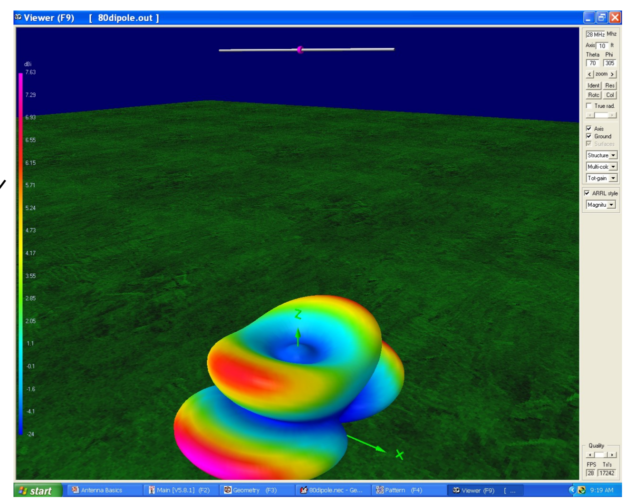
Comparison Between ½ WL Trapped and Open-Wire Center fed Antennas

½ WAVE
DIPOLE

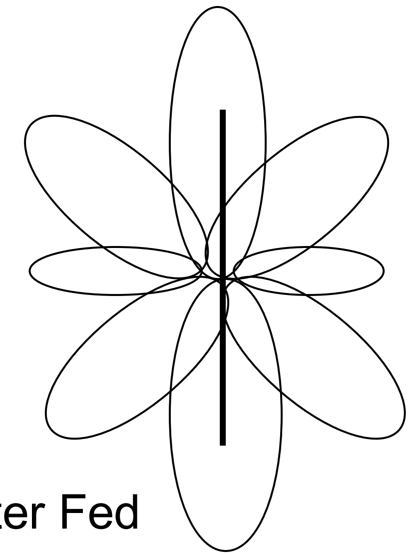




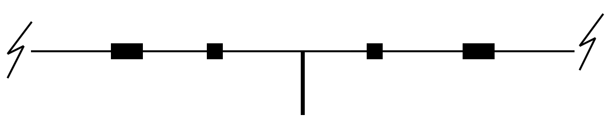
Each 10 m antenna at 35 ft



130 ft (7 WL)
DIPOLE

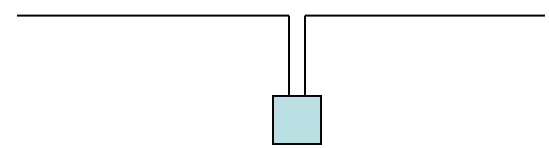


Trapped



Coax feedline
(Narrower BW and
fewer bands)

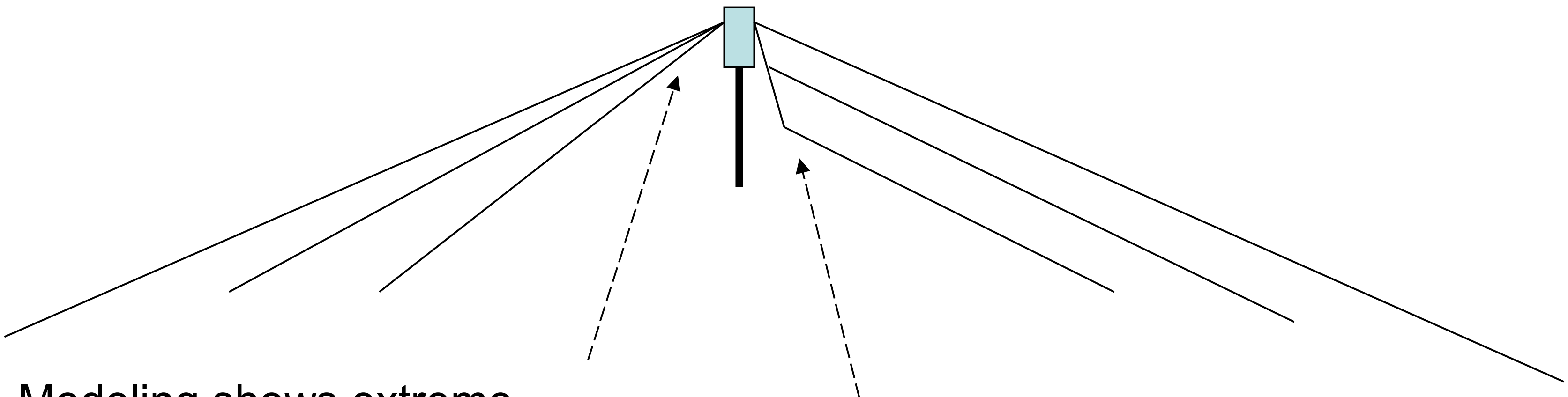
Center Fed



Open feedline
and Tuner

MULTIBAND

Parallel (Fan) Multiband Antenna



Modeling shows extreme difficulty tuning –especially on 15 m

-I've had good luck with two bands (80 and 40 m)

With more spacing, modeling shows easier tuning and better SWR when more bands are added

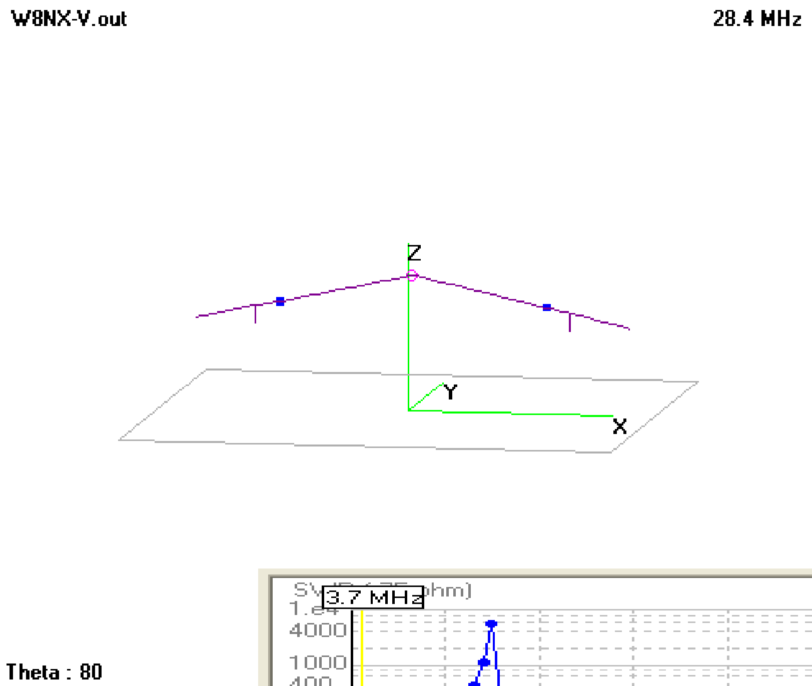
I think this is a Morgan Trap
(H K Morgan 1940 -CQ Mag Feb 1977)
-Requires calculations to determine the value of coil X_L

Alpha-Delta Fan/Trapped Dipole

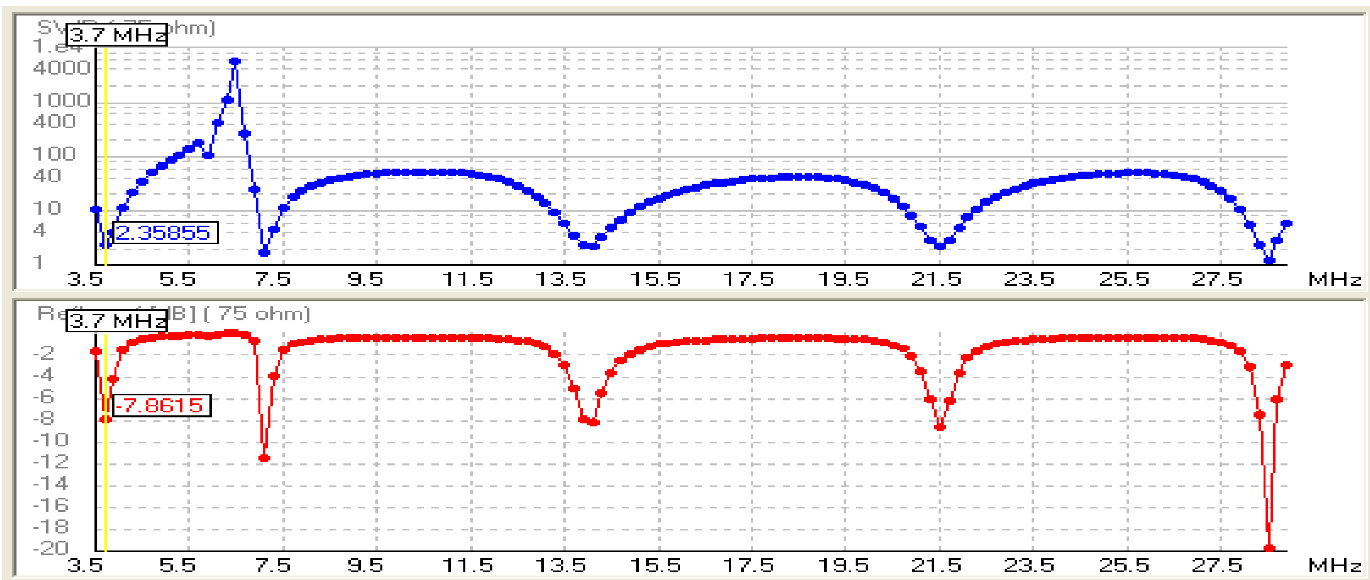
F_1 (20 m) + X_L + Wire = F_2 (40 m)

MULTIBAND

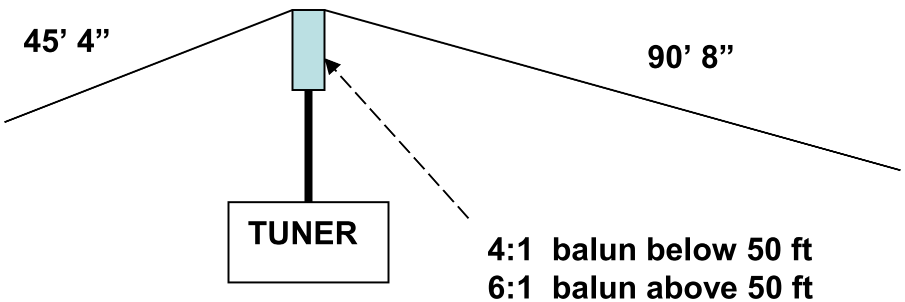
80 – 10 m W8NX 5-Band Dipole Antenna –My Choice



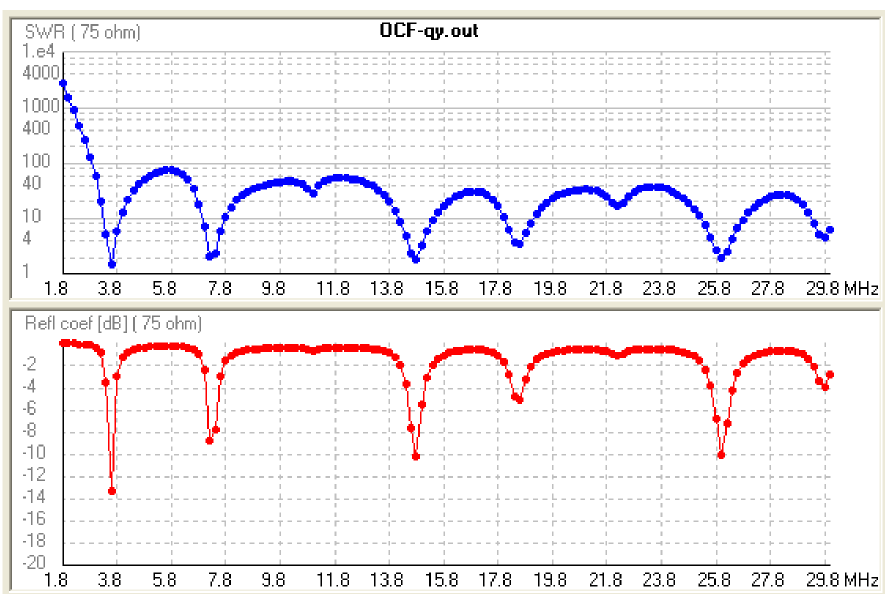
- -Coax fed – SWR below 3:1 on all bands
- -No external tuner required
- -40 m trap and 20/15/10 m stubs
- -Full-sized performance 80/40 m
- -20, 15, and 10 m have multiple lobes

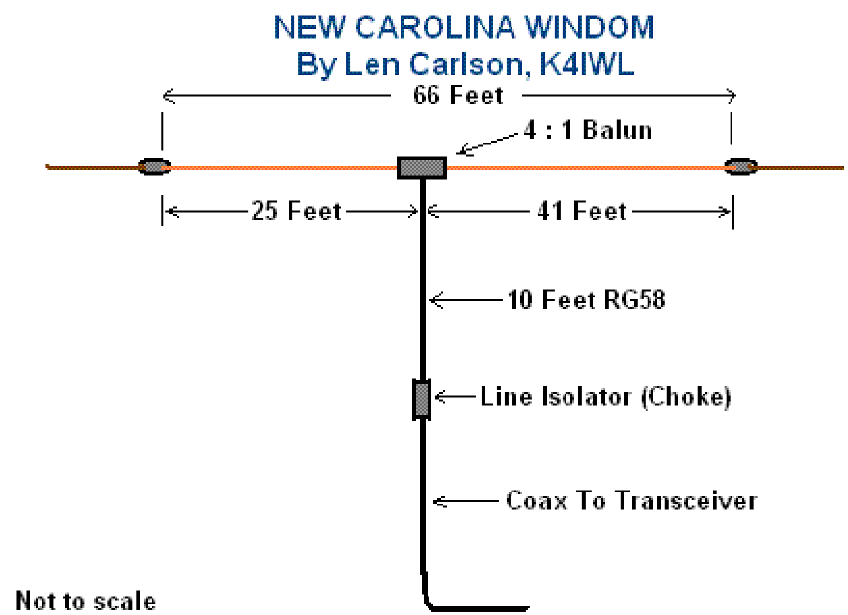


MULTIBAND
Off-Center-Feed and Windom Antennas



- -Requires a Tuner
- -High bands have multiple lobes

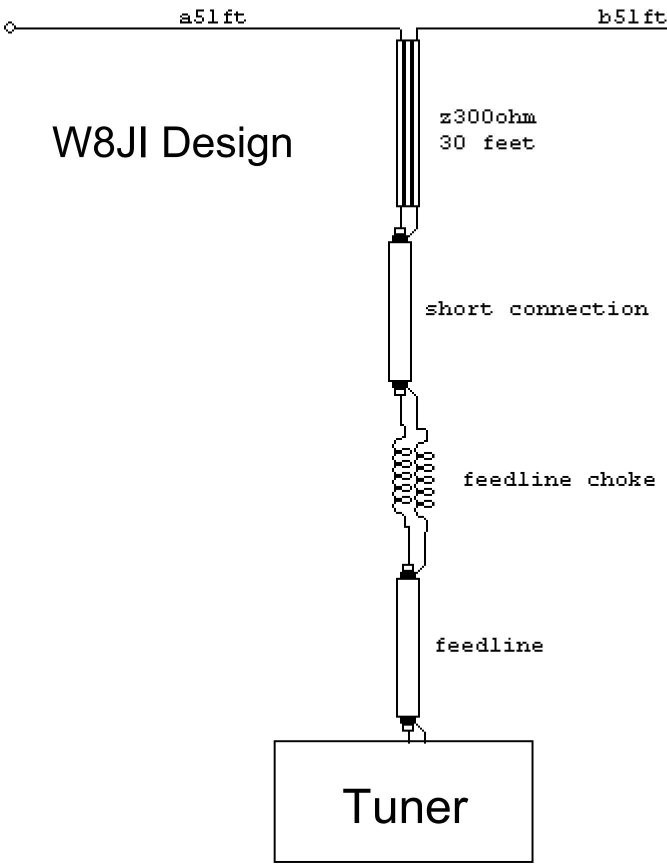




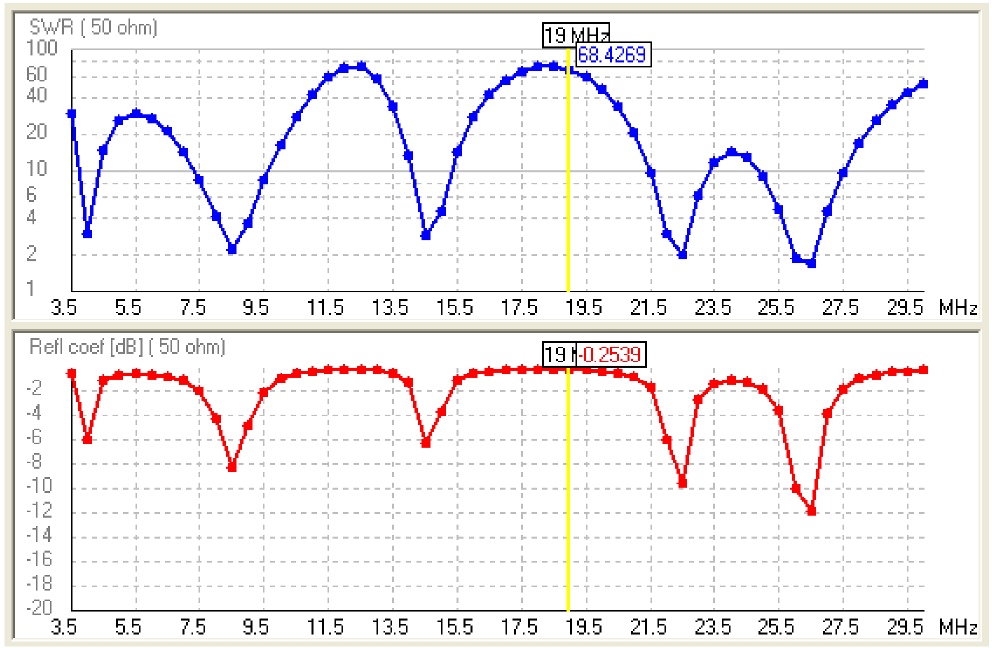
MULTIBAND

G5RV Antenna

W8JI Design



	80	40	20	30	15	12	10
SWR	2.71	4.1	1.9	Hi	5.5	2.6	Hi

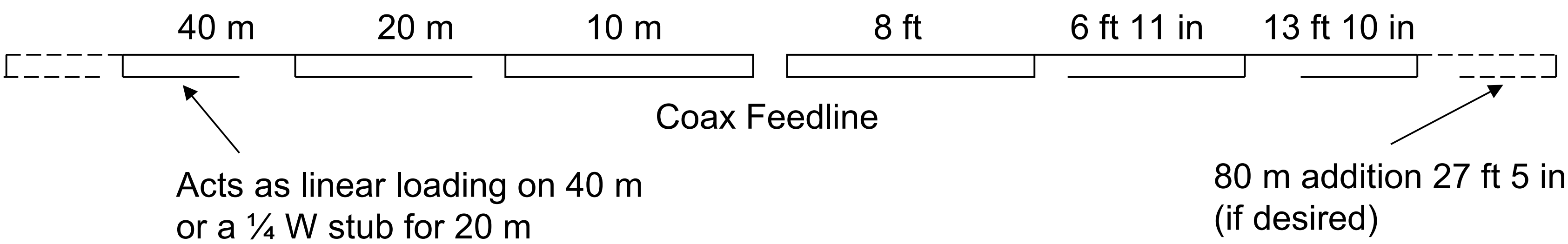


MULTIBAND

Decoupling Stub Multiband Dipole

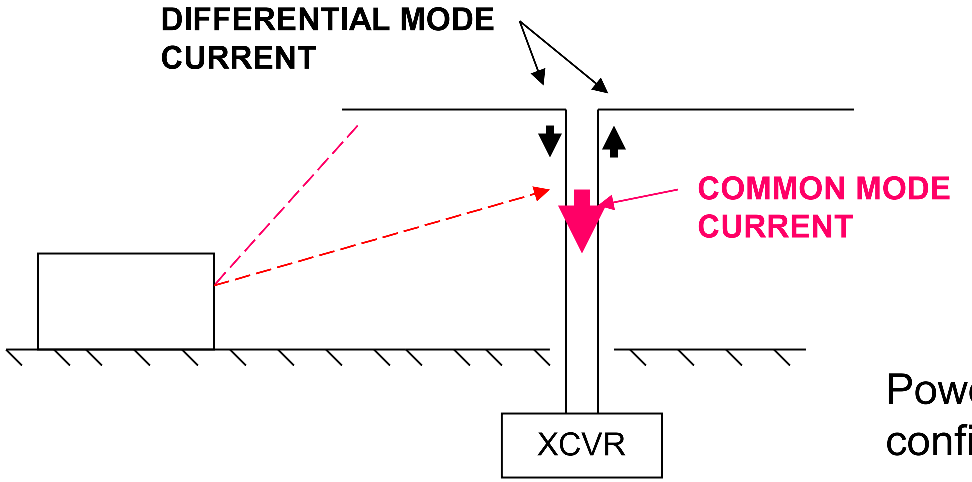
Lattin Dipole -W4JRW

10/20/40 Meter Short Dipole Using 300-Ohm Twinlead



A Future Antenna Project

RF CHOKES

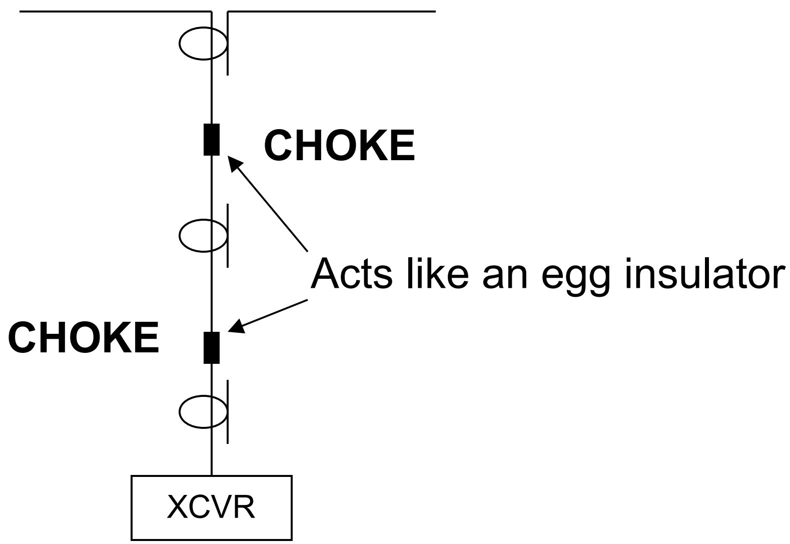


Why Use a Choke?

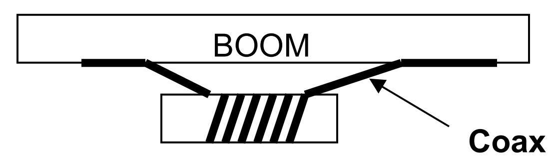
-Isolate antenna from feed line
-Reduce noise
-Keep RF out of the shack

Power (and field) is confined inside the coax

Common Mode power (and field) is outside coax

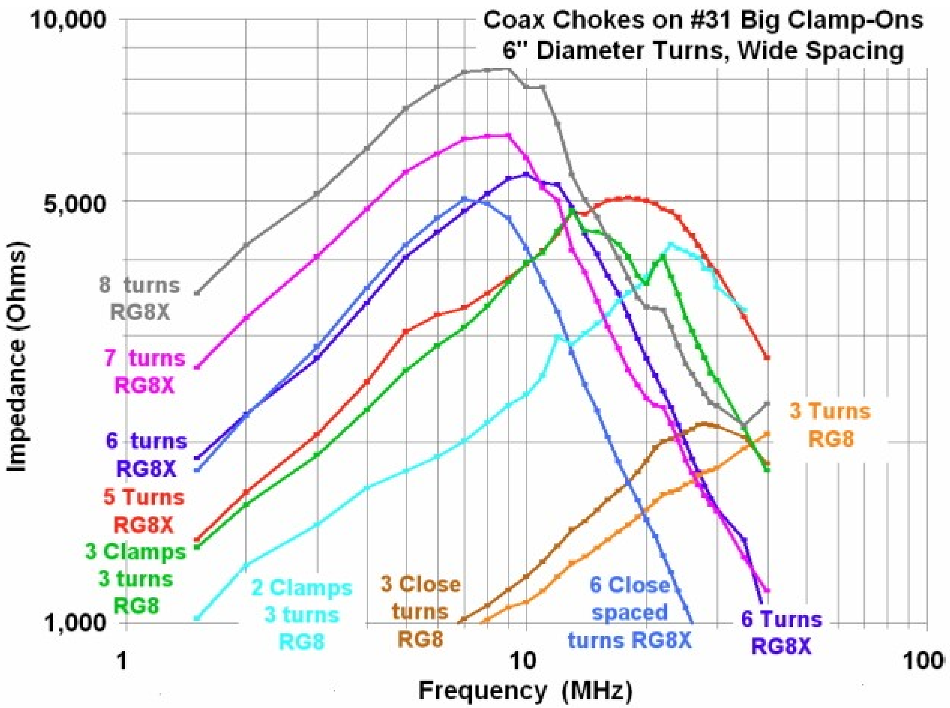


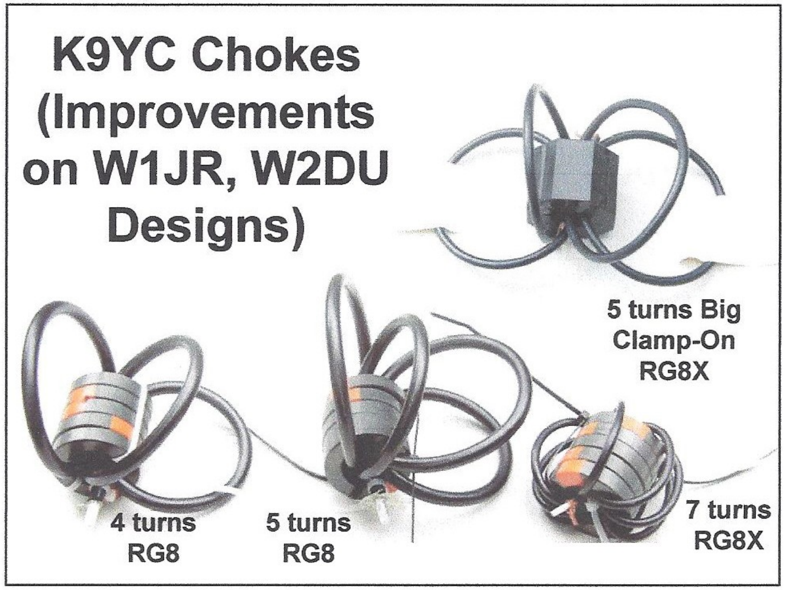
20 to 10 m Yagi Choke



Six turns on 4” PVC sewer pipe attached away from the boom to prevent coupling via the boom (12 turns for 40 to 30 m)

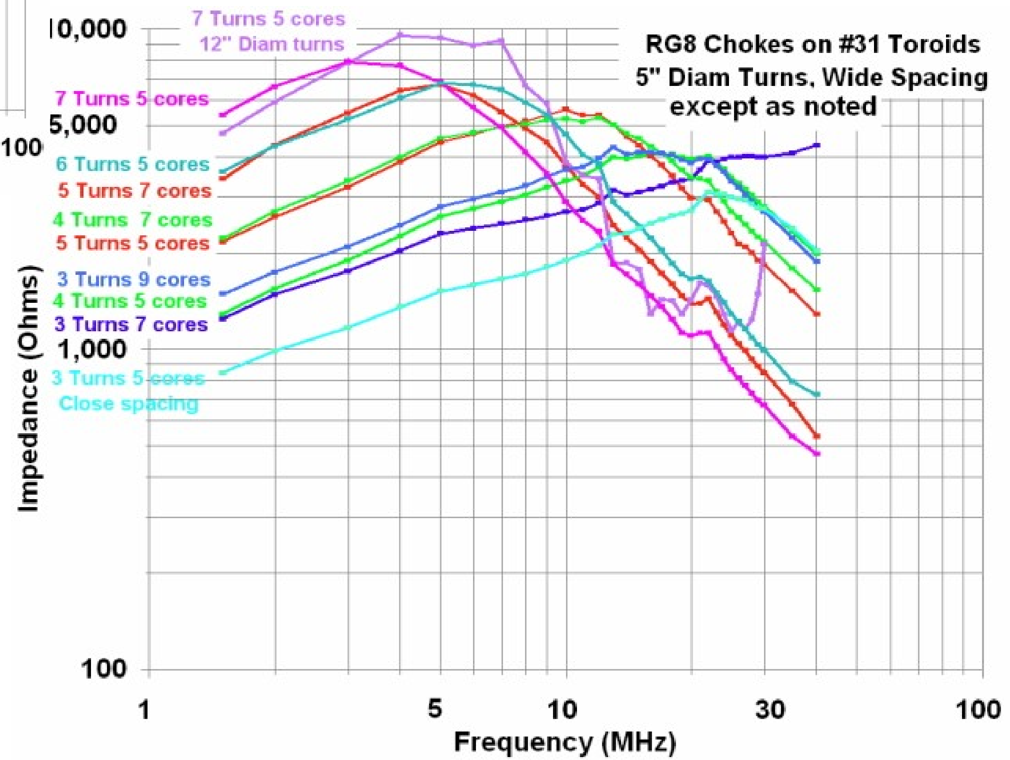
RF CHOKES



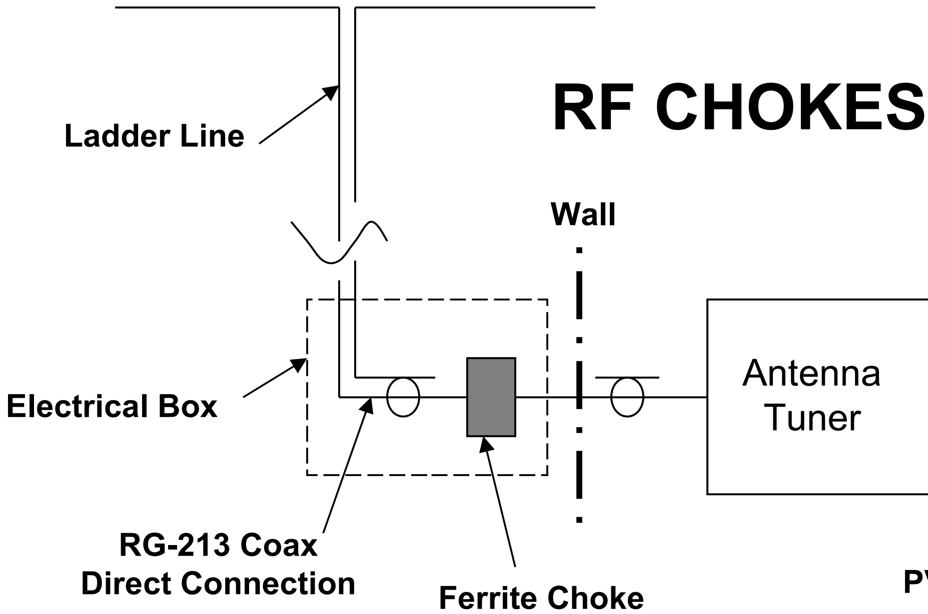


Data from K9YC's webpage:

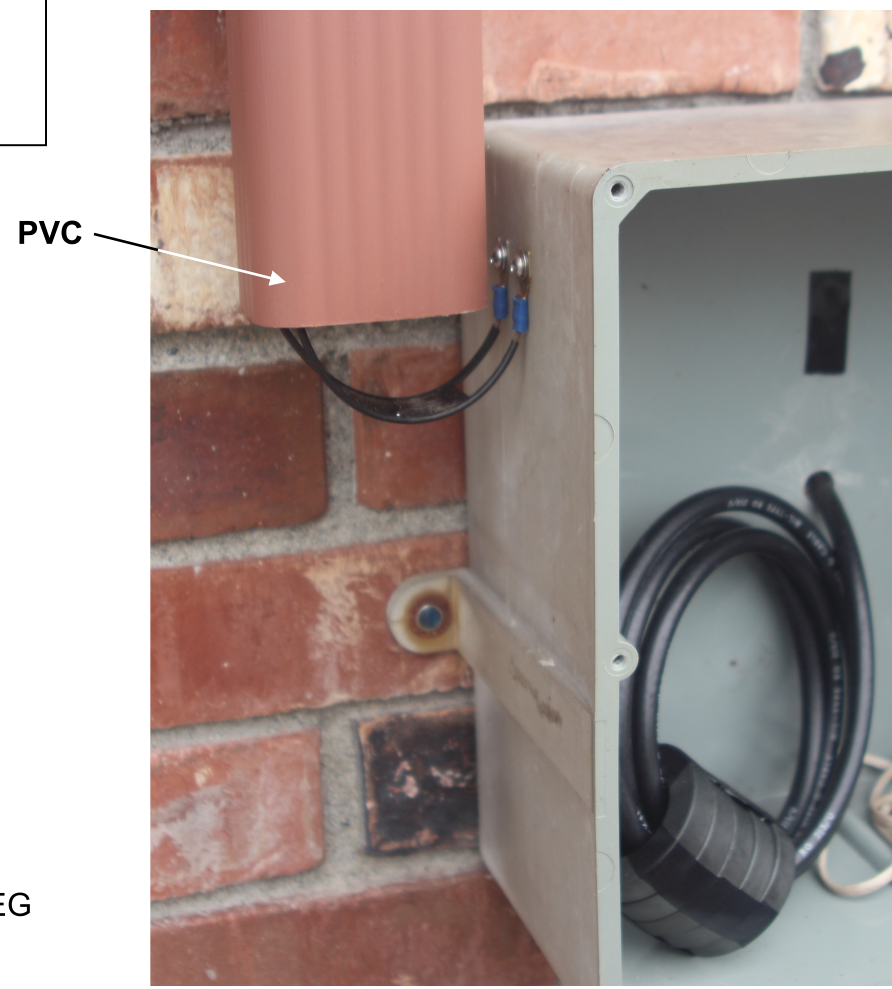
http://audiosystemsgroup.com/NCDXACoaxChokesPPT.pdf



RF CHOKES



Thus, making sure that there are no common mode currents present is the key objective, both to minimize noise pickup and to make sure that there are no currents that could couple into the house wall. The feed line choke does that very well.



A resonant antenna will never have a feed impedance of 400+j0. It will be a low impedance near it's resonant, 3rd harmonic, etc. On the even harmonics, it will have a high impedance. Thus, the 400-Ohm ladder line never shows an impedance anywhere close to 400 Ohms at the transmitter. Thus, a specific impedance matching ratio is never correct. That's why there's an antenna tuner inside the shack - to match whatever impedance is seen to the 50 Ohms that the transmitter wants.

-Courtesy of Tom McDermott –N5EG

THE END

K5QY