ANTENNA BASICS FOR BEGINNERS

PART 1 –VERTICAL ANTENNAS

INTRODUCTION

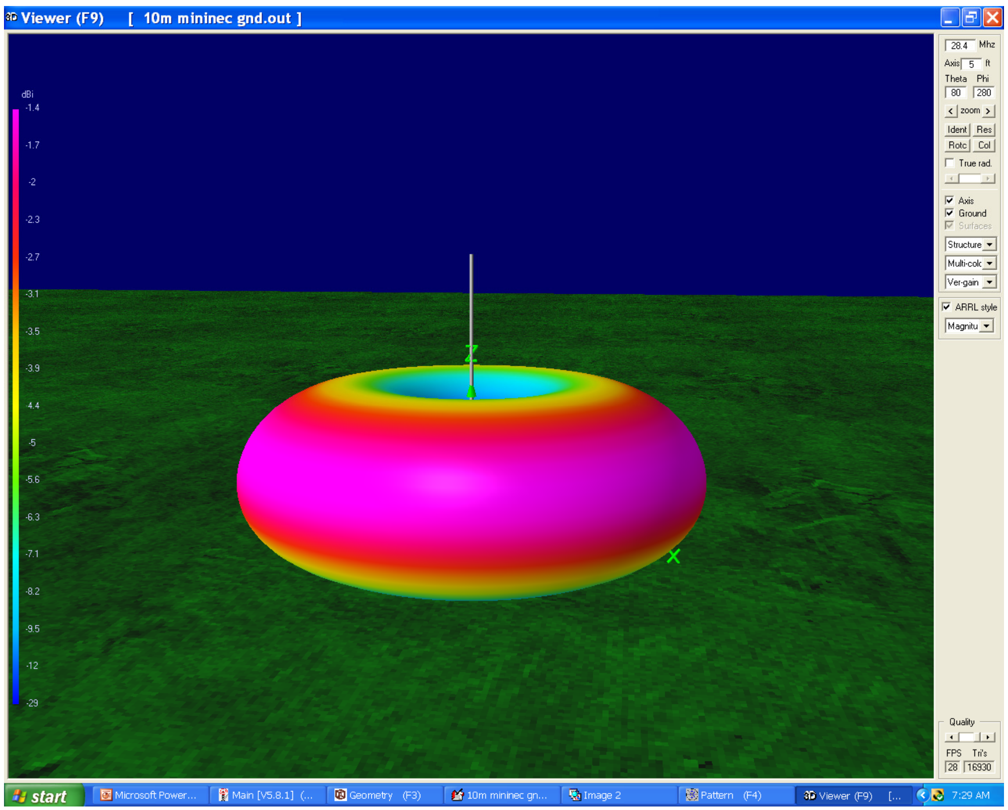
VERTICALS

MULTIBAND VERTICALS

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

HOW DO ANTENNAS WORK?

An Antenna Is A Basic Transducer

For transmitting, you generate an electrical RF signal on a conductor.
As a result:

-**Electric (E)** fields arise from a voltage rapidly changing

-**Magnetic (M)** fields arise from a current rapidly changing

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.

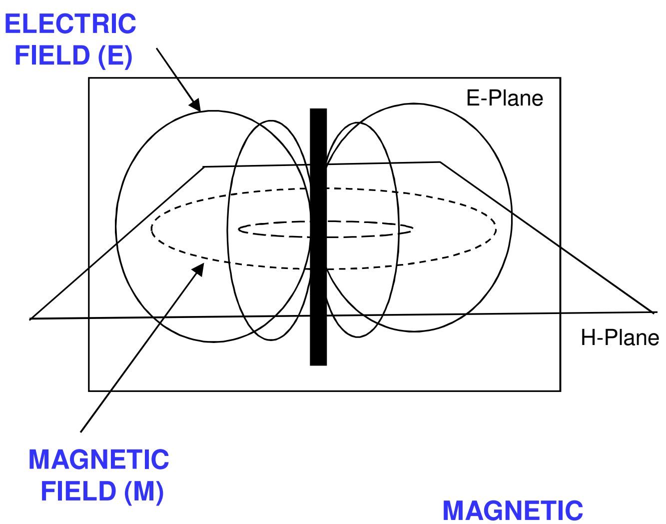
Generally people don't think of radio-frequency radiation in terms of discrete particles (oscillating electrons and photons)
-they typically use the **Wave Model** instead, as it's much easier to use.

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.

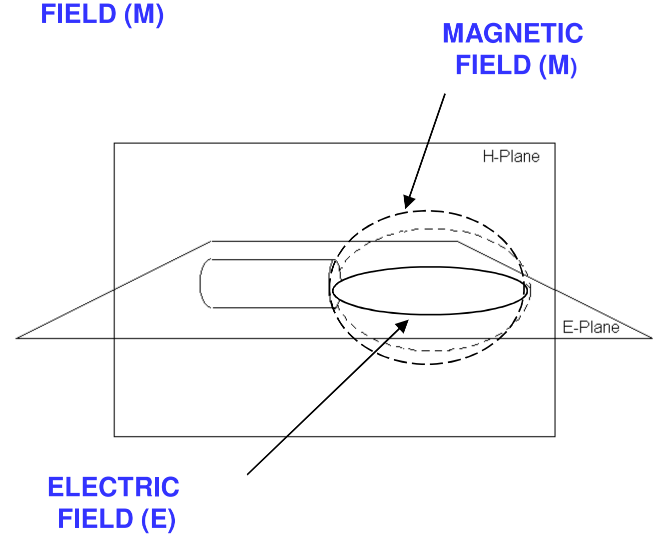
For a horizontally-polarized antenna, the E-plane usually coincides with the horizontal/azimuth plane.



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

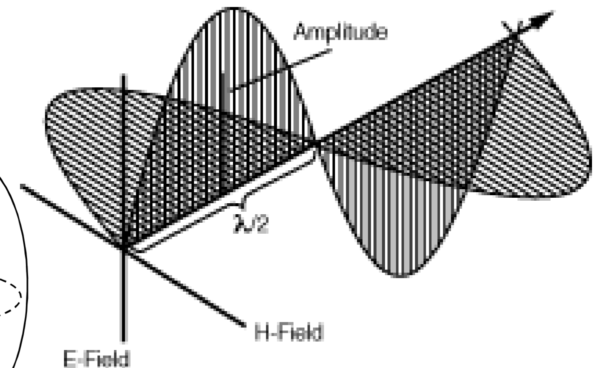
For a vertically polarized antenna, the H-plane usually coincides with the horizontal/ azimuth plane.

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



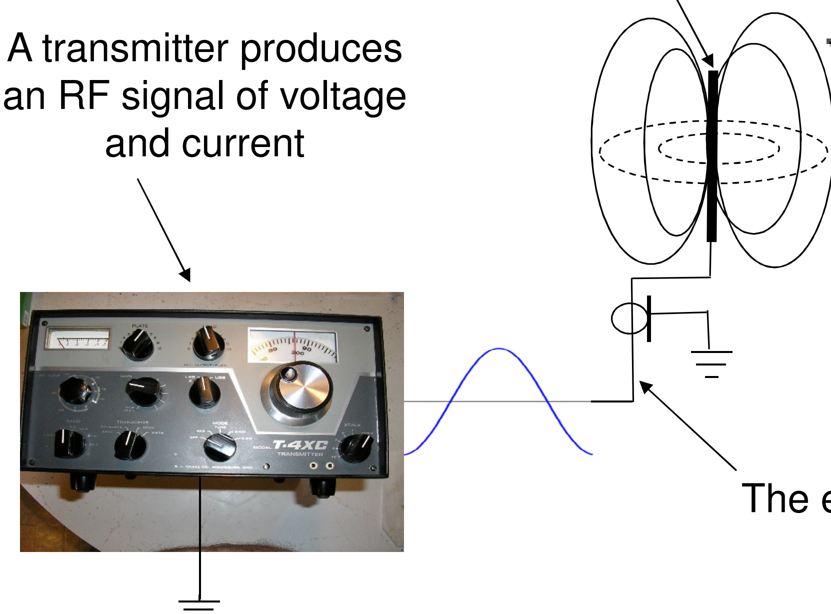
VERTICAL POLARIZATION

A Vertically polarized EM wave
Is produced



A vertical's electrons are
excited by the RF signal and
E and H fields arise

A transmitter produces
an RF signal of voltage
and current



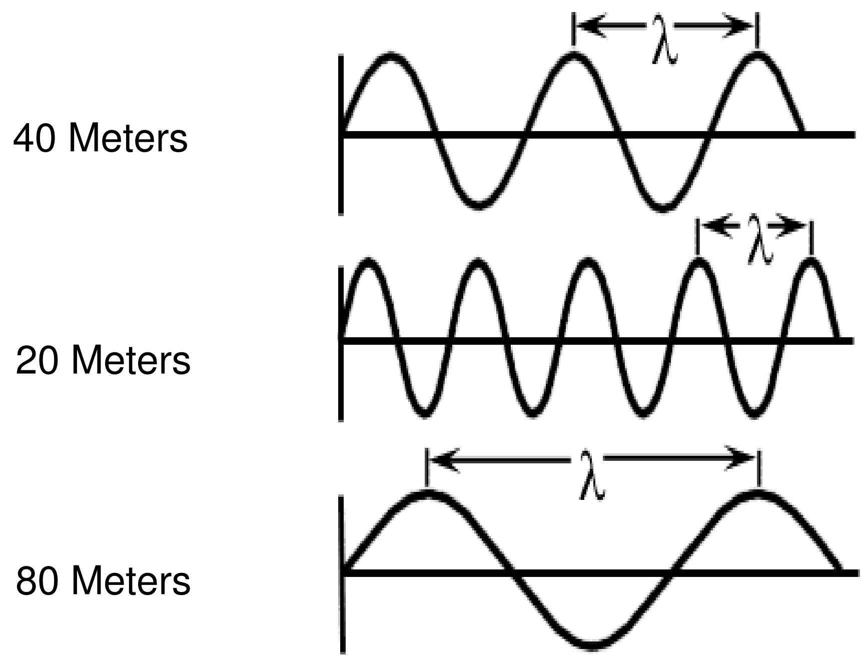
The electrical RF signal is connected
to the antenna via coax

ANTENNA LENGTH IN METERS

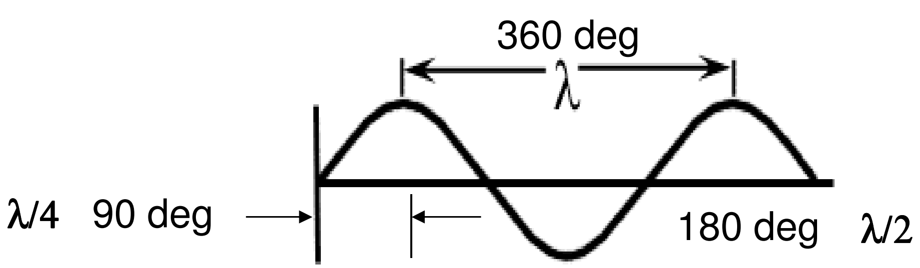
Antenna Length is usually described as wavelength (WL) in **meters** or **degrees**:

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

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



ANTENNA LENGTH IN DEGREES



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24.9	12	37.6
28.5	10	33
52	6	18

Example: 50 ft vertical used on 160 m

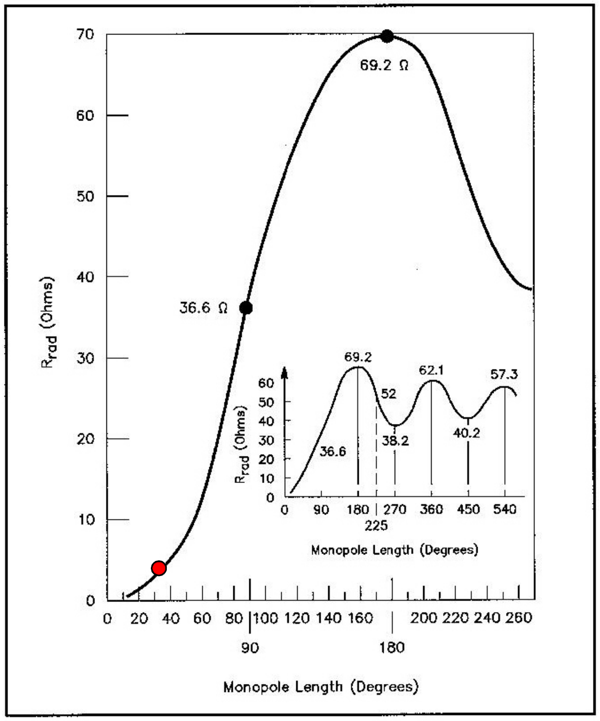
$$\frac{\text{360 degrees}}{\text{degrees}} = \frac{\text{Freq WL (ft)}}{\text{Ant Length (ft)}}$$

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

360 X 50 / 510 = **34.6 degrees**

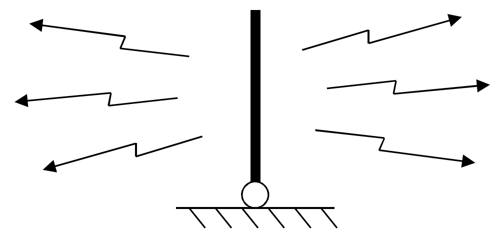
VERTICALS

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.



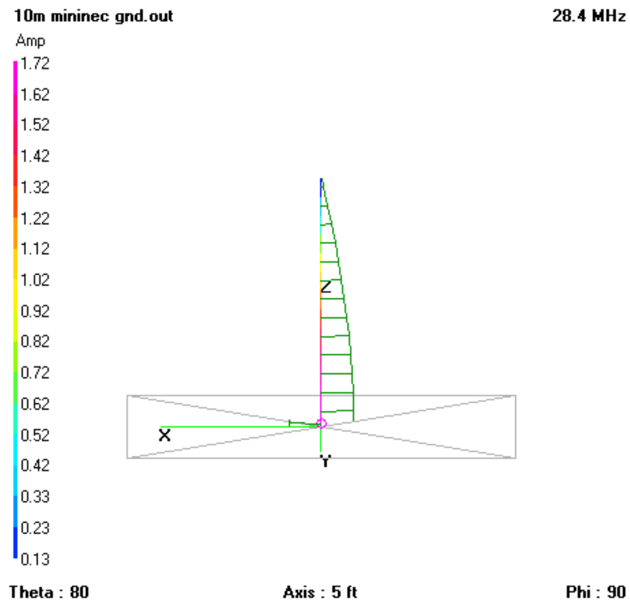
Radiation Resistance =
Power radiated / input current squared

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 R_{rad}

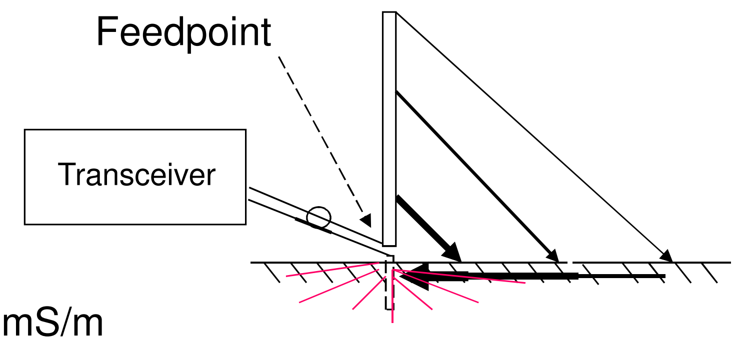
VERTICALS

Ground Losses (R_{gnd}) and Current Flow



The further up the element the less current flows

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)

VERTICAL FEEDPOINT RESISTANCE and EFFICIENCY

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

AND

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

Rin – Feedpoint resistance at **resonance**

$X_c = X_L$ or $jX = 0$

Rrad – Radiation resistance
Rgnd – Ground resistance
RL – Loading resistance
Rs – Structural resistance

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%

VERTICAL MATCHING –SWR
(Standing Wave Reflection)

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

Feedpoint Resistance (R_{in}) =
(At Resonance)

30 Ohms = 20%

25 Ohms = 24%

20 Ohms = 30%

$$\textbf{SWR} = \frac{R_{in}}{\text{Coax } Z} \quad \text{or} \quad \frac{\text{Coax } Z}{R_{in}}$$

(use the larger number on top)

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

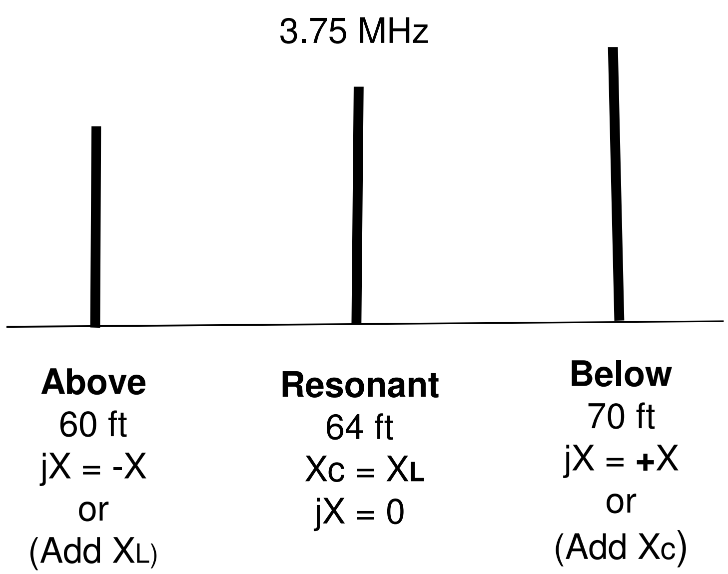
$$\text{SWR} = \frac{\text{50-Ohm Coax}}{\text{30 Ohms } R_{in}} = 1.66{:}1$$

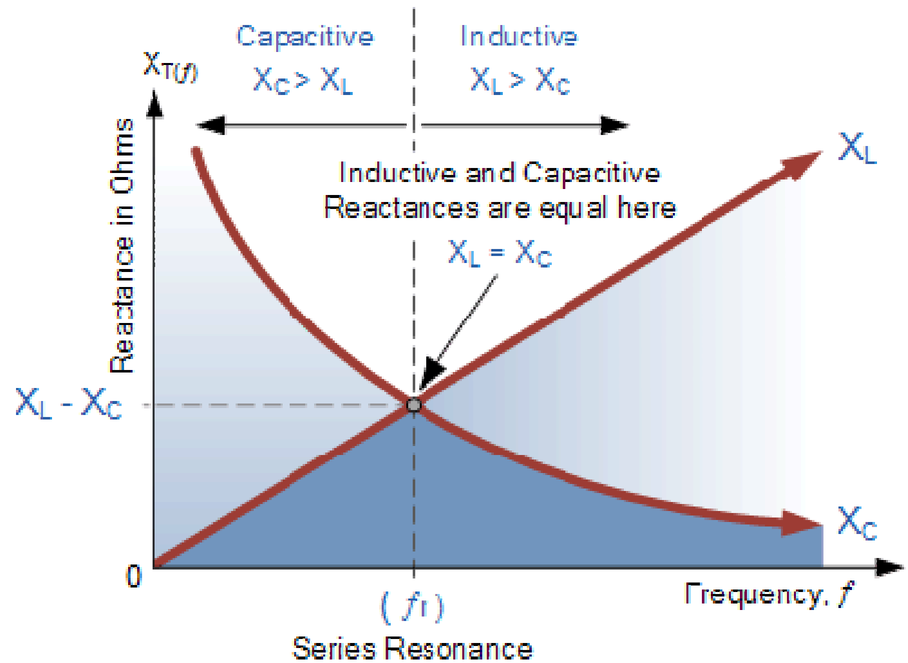
$$\text{SWR} = \frac{\text{50-Ohm Coax}}{\text{25 Ohms } R_{in}} = 2{:}1$$

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

VERTICALS

Antenna RESONANCE occurs when $X_L = X_C$ or $jX = 0$

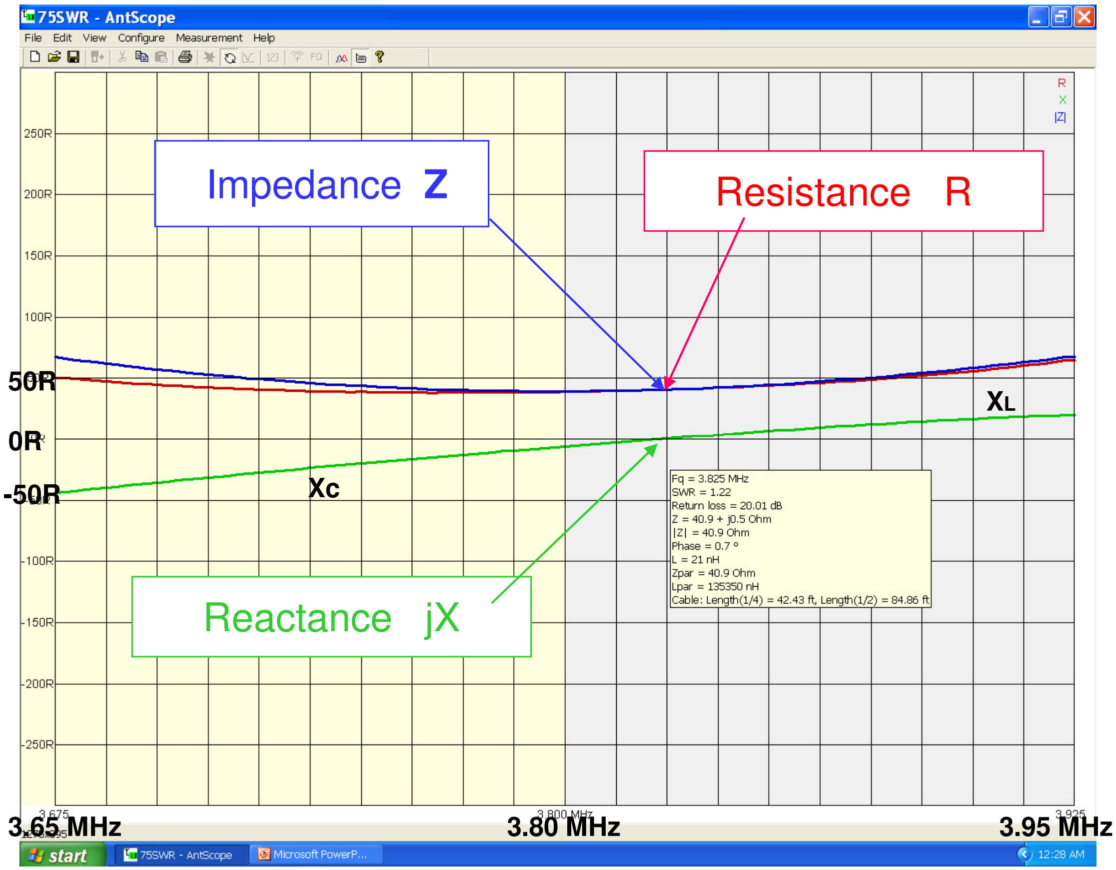




VERTICALS

Feedpoint IMPEDANCE (Z) is the mathematical combination of R and X or:

$$Z = \sqrt{R^2 + (X_L - X_C)^2}$$



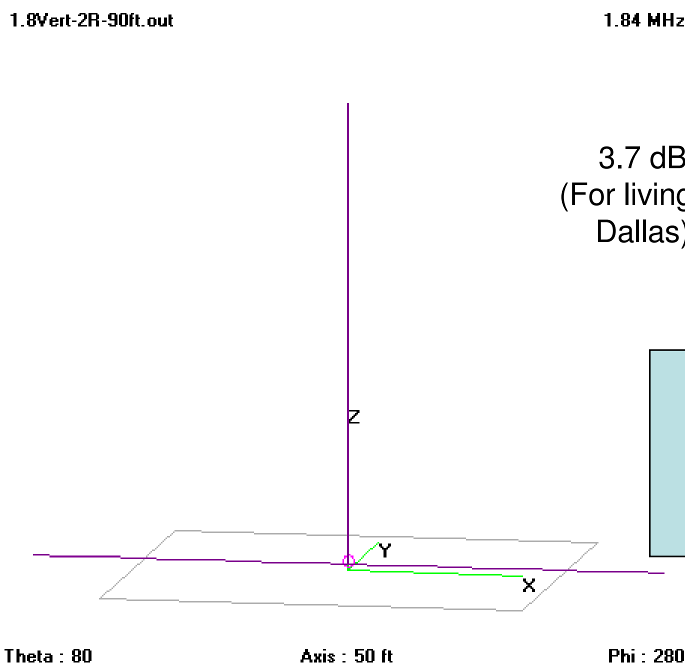
Actual HyGain 18HT Vertical Impedance Data

MFJ 269 ANALYZER

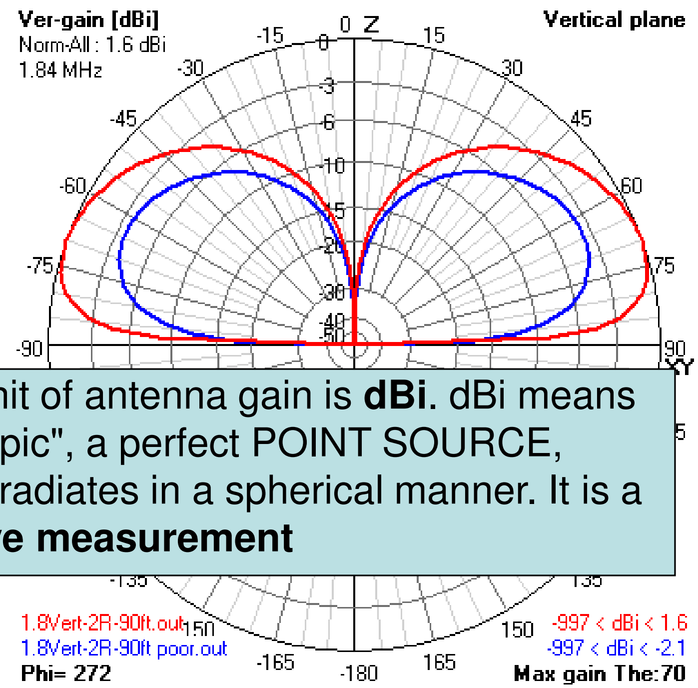
VERTICALS

160 m Vertical with two 90 ft radials

Comparison between poor ground and good ground



3.7 dB
(For living in
Dallas)

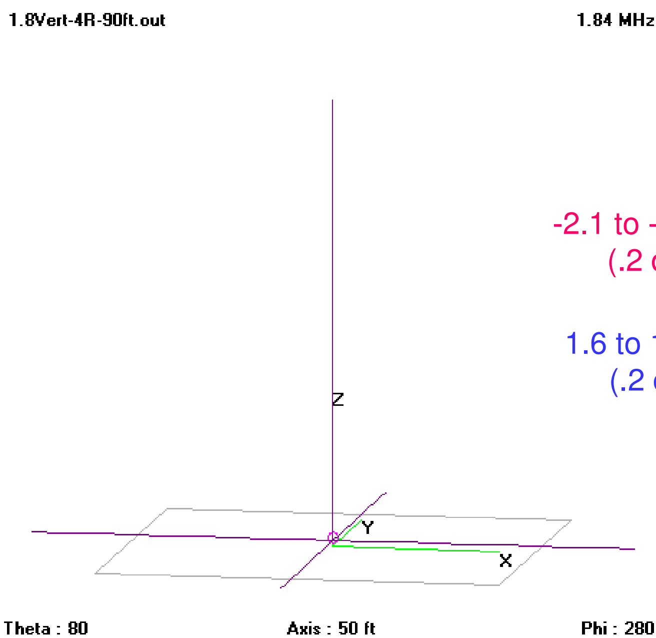


The unit of antenna gain is **dBi**. dBi means "Isotropic", a perfect POINT SOURCE, which radiates in a spherical manner. It is a **relative measurement**

VERTICALS

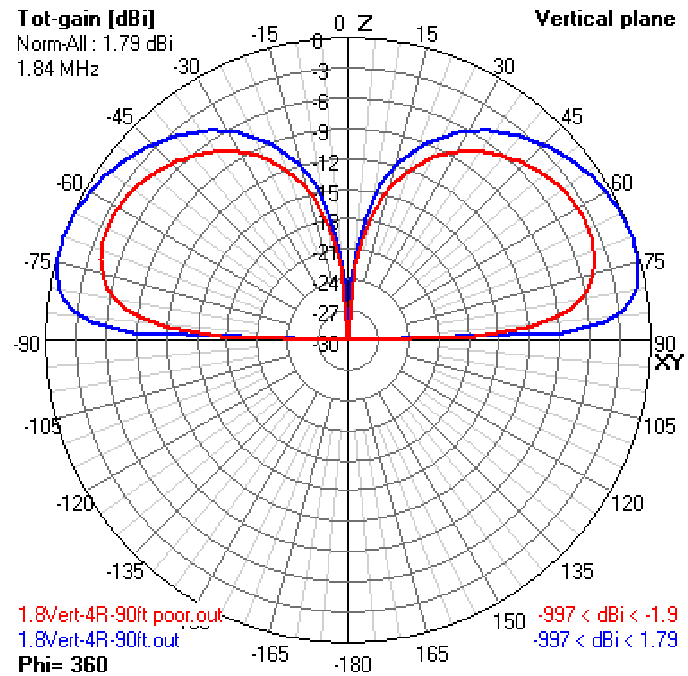
160 m Vertical with four 90 ft radials

Comparison between poor ground and good ground



-2.1 to -1.9 dBi
(.2 dB)

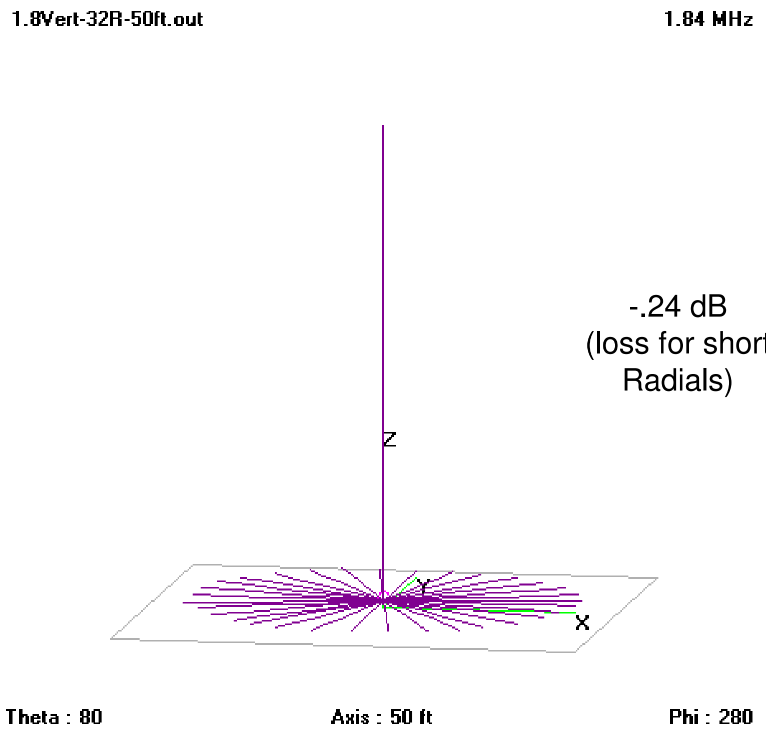
1.6 to 1.8 dBi
(.2 dB)



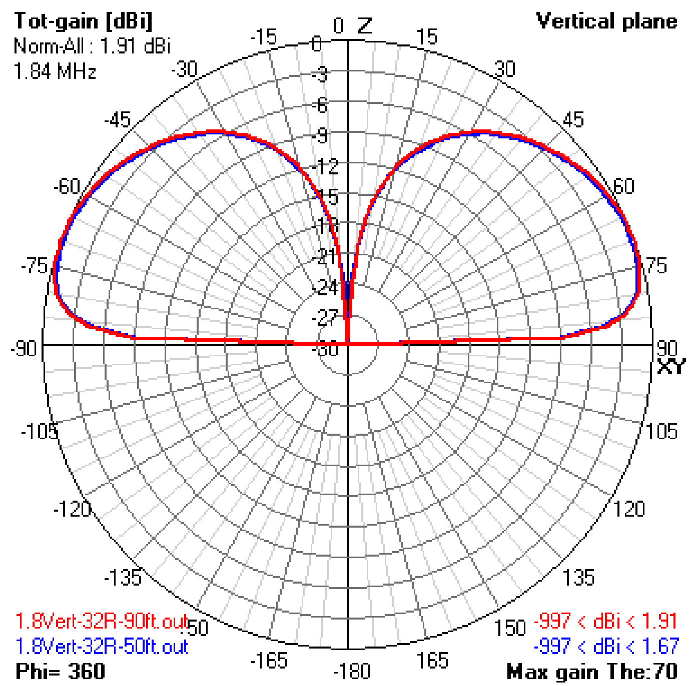
VERTICALS

160 m Vertical with thirty-two radials

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



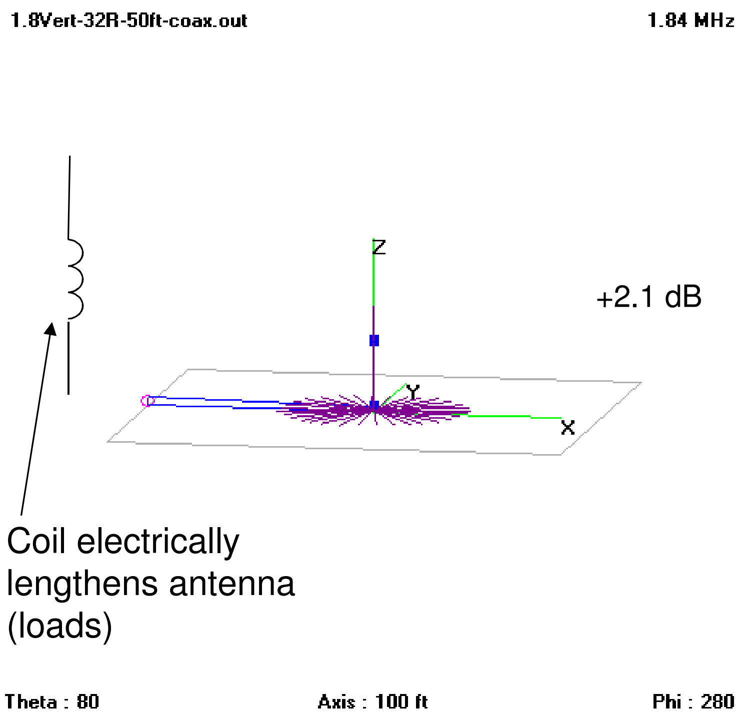
-.24 dB
(loss for short
Radials)



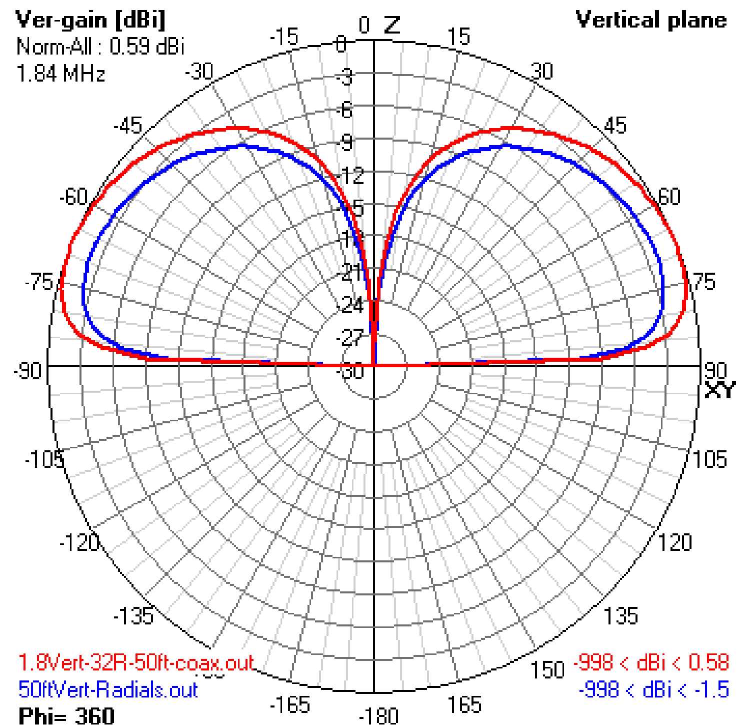
VERTICALS

50 ft Shortened 160 m Verticals with 32 Radials

Comparison between Inductively (coil) baseloaded and centerloaded



+2.1 dB

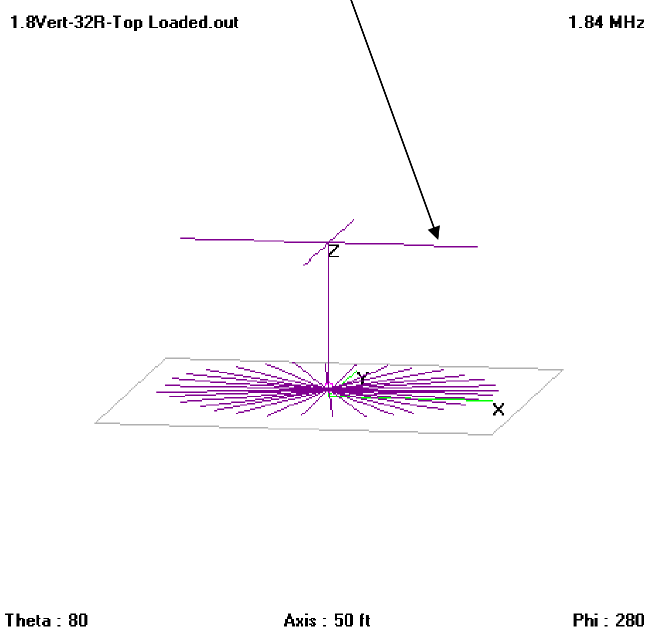


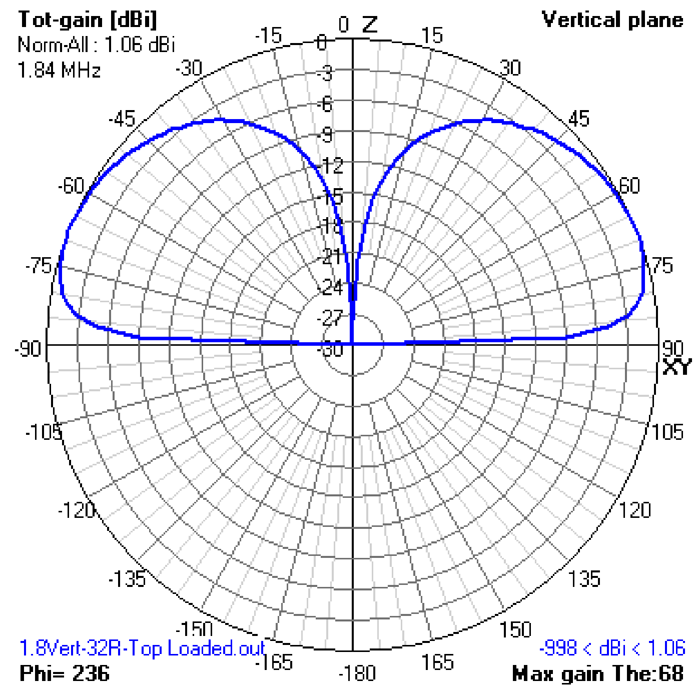
VERTICALS

50 ft Shortened 160 m Verticals with 32 Radials

Capacitive (Top Hat) Loaded

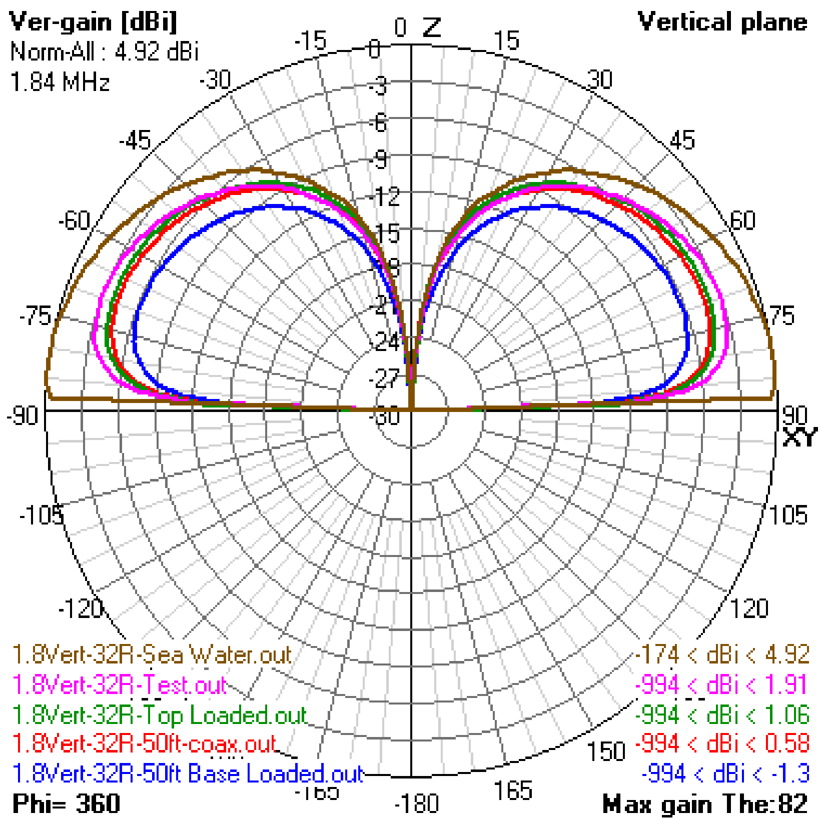
Capacitive loading
Electrically lengthens
antenna





VERTICALS

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

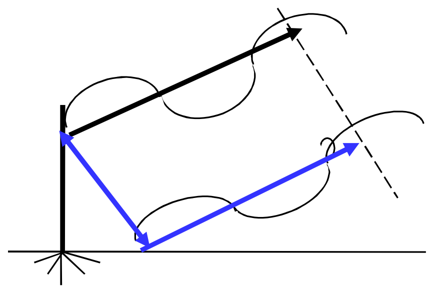


	Rad Eff	Gain	Loading
Base Loaded	23.3%	-1.5 dBi	40.7 W
Center Loaded	37.3%	0.58 dBi	24 W
Top Loaded	41.8%	1.06 dBi	---
Full Size	45.6%	1.67 dBi	---
FS Sea Water	95.1%	4.92 dBi	---

VERTICALS

Radiation Pattern

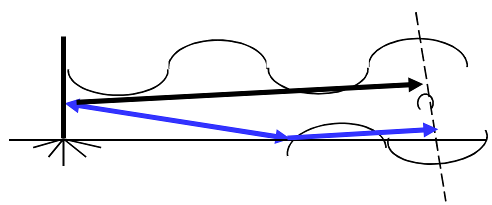
Near Field is the area where the ultimate pattern is not fully formed, and E-H induction fields have a noticeable effect on forces we measure.



Signal reflection at an in-phase point
(Augmentation)

Simple verticals have the Frensel zone extending out a few wavelengths. Physically large arrays almost always have a large Frensel zone.

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



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

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

PSEUDO-BREWSTER ANGLE

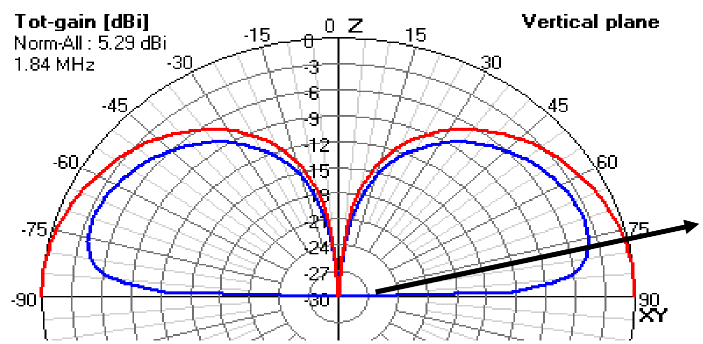
Pseudo-Brewster Angle (PBA): varies with the ground conductivity and dielectric constant.

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.

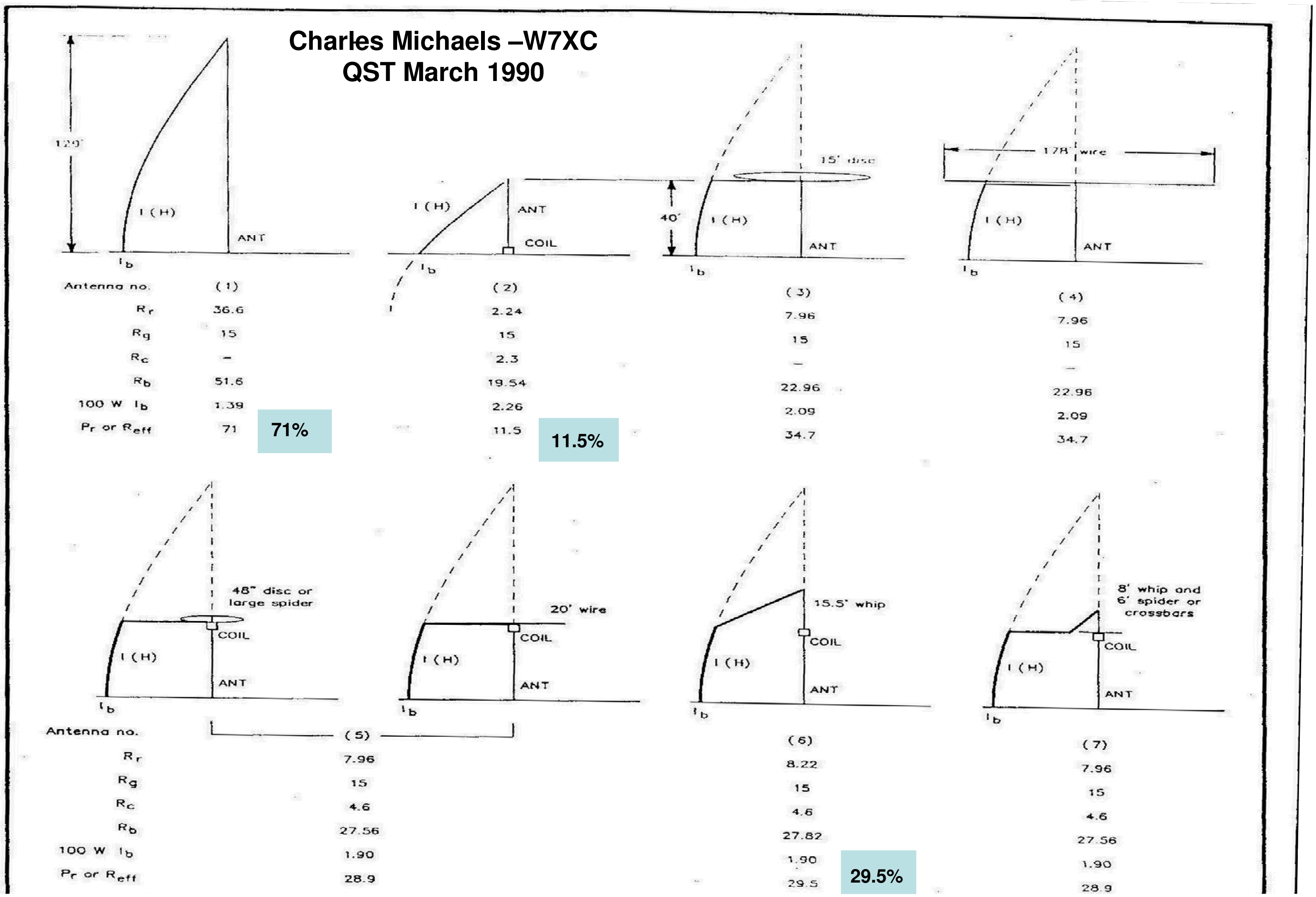


Pseudo-Brewster Angle is typically at the -4 dB point from "perfect" ground

-Courtesy of Tom McDermott –N5EG

Vertical Efficiency

Charles Michaels –W7XC
QST March 1990



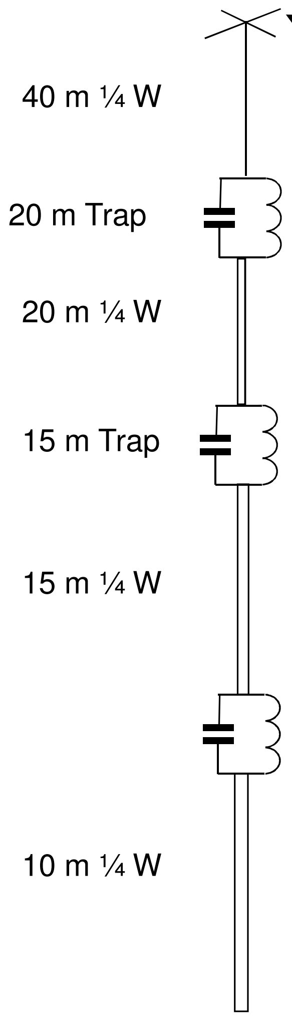
Antenna no.	(1)	(2)	(3)	(4)
R_r	36.6	2.24	7.96	7.96
R_g	15	15	15	15
R_c	–	2.3	–	–
R_b	51.6	19.54	22.96	22.96
100 W I_b	1.39	2.26	2.09	2.09
P_r or R_{eff}	71	11.5	34.7	34.7

71% 11.5%

Antenna no.	(5)	(6)	(7)
R_r	7.96	8.22	7.96
R_g	15	15	15
R_c	4.6	4.6	4.6
R_b	27.56	27.82	27.56
100 W I_b	1.90	1.90	1.90
P_r or R_{eff}	28.9	29.5	28.9

29.5%

VERTICALS



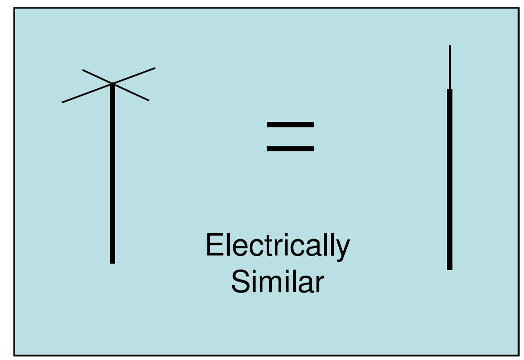
Capacity Loading (top hat)
-Electrically lengthens element

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

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

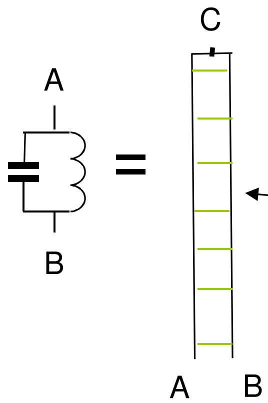
L-C Trapped Multiband



VERTICALS

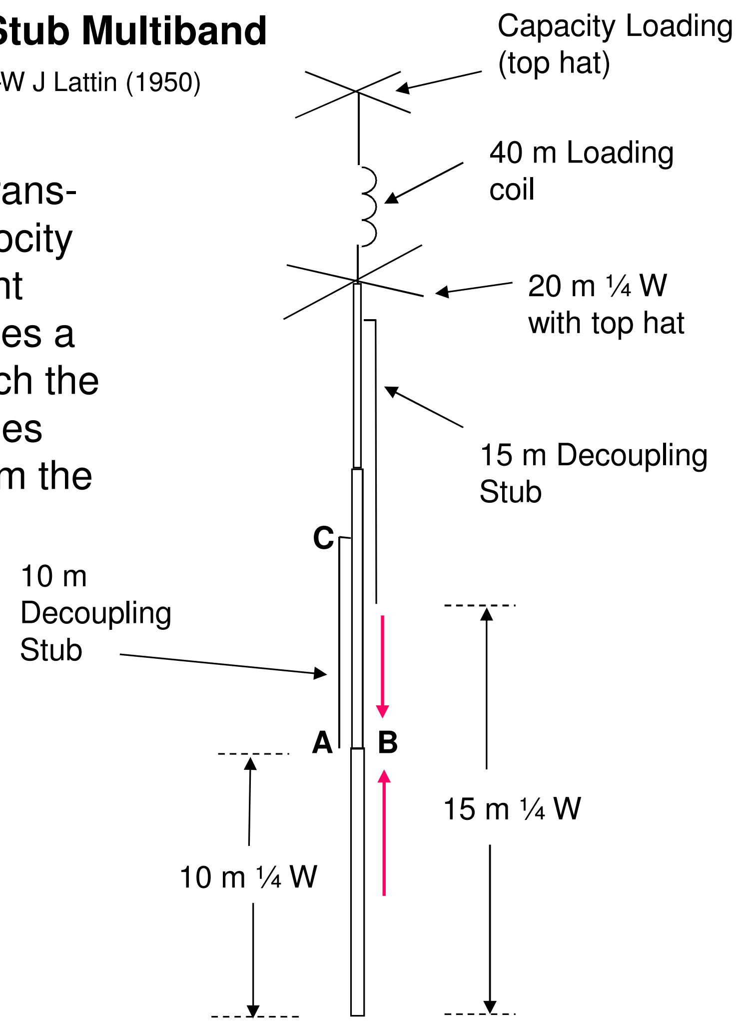
¼ W Decoupling Stub Multiband

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

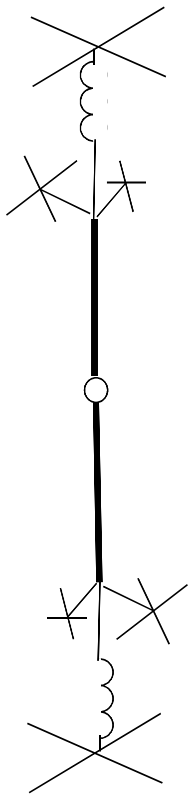
A different connection is possible -that is **A** to **C**. This results in an insulator action or decoupling



VERTICALS

Ground Independent Multiband Antennas

Electrical
Equivalent



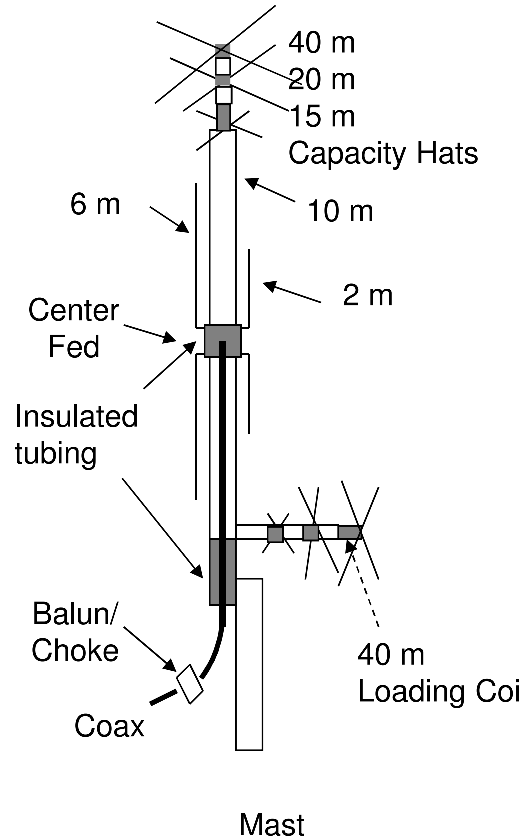
Vertically Polarized
Loaded Dipole

Remember Hustler HF Mobile antennas?

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

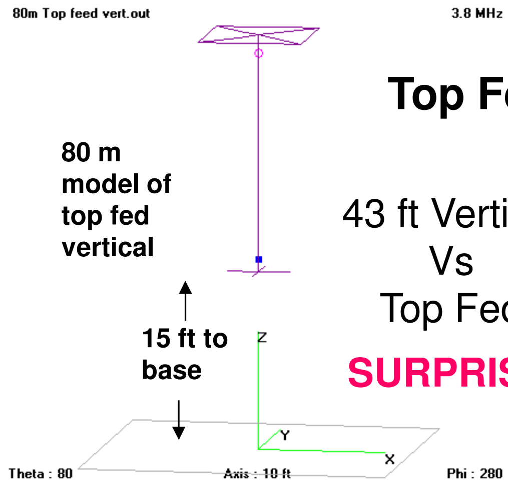
Just put to two of them back-to-back
and use three resonators and there
you have it

-Narrow bandwidth on 20 and 40 m



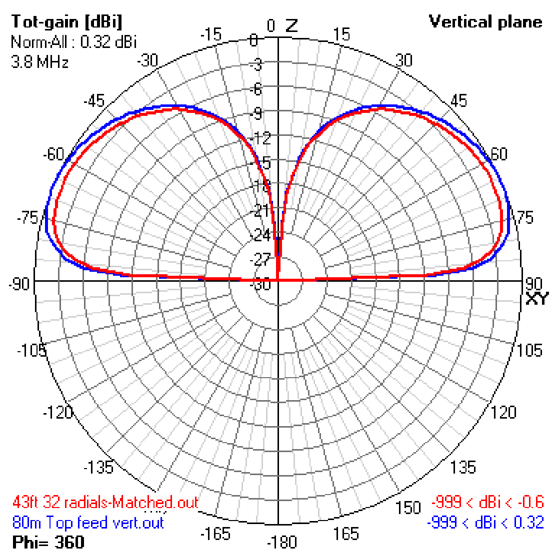
VERTICALS

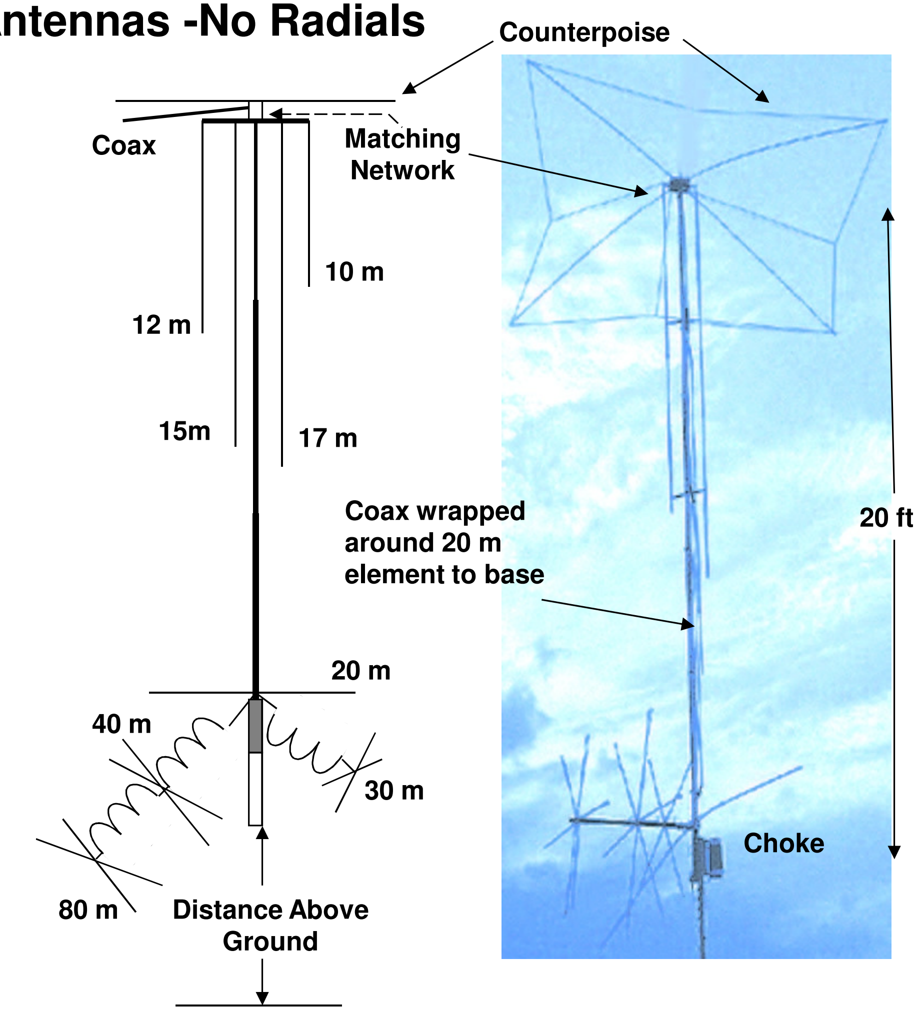
Top Fed Antennas -No Radials



43 ft Vertical
Vs
Top Fed

SURPRISE!

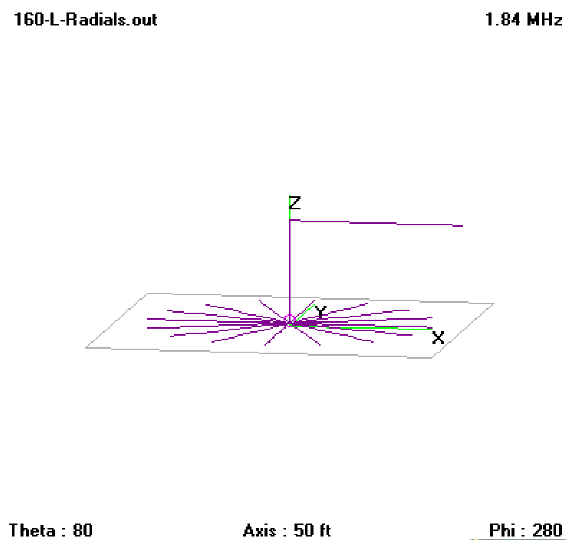


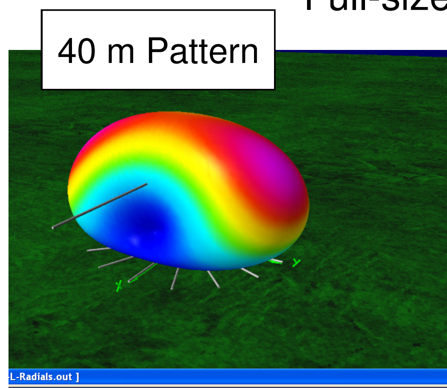


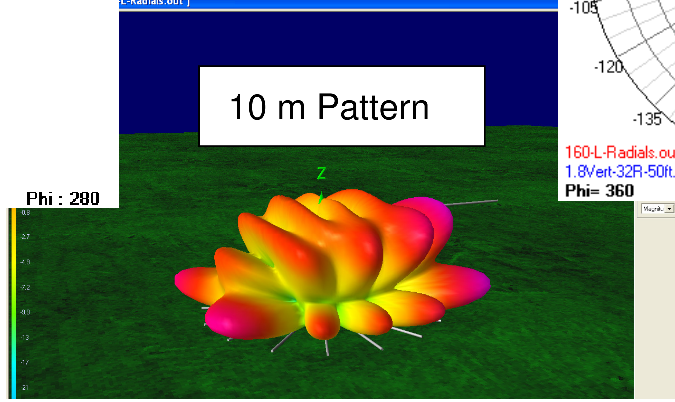
INVERTED-Ls and LONG WIRES

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

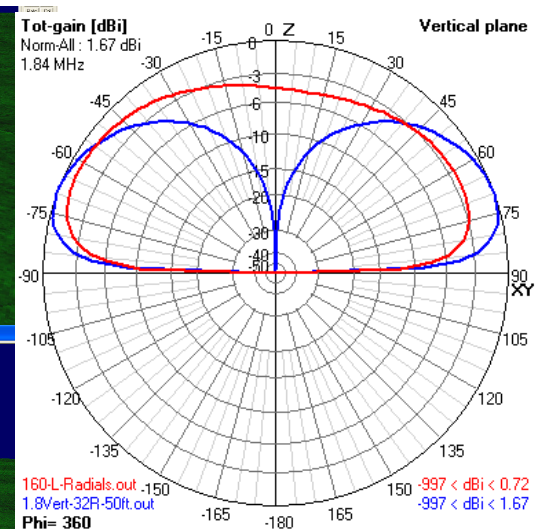
37 ft high X 90 ft long







Full-size vertical Vs Inv-L comparison



VERTICALS

THE END

K5QY