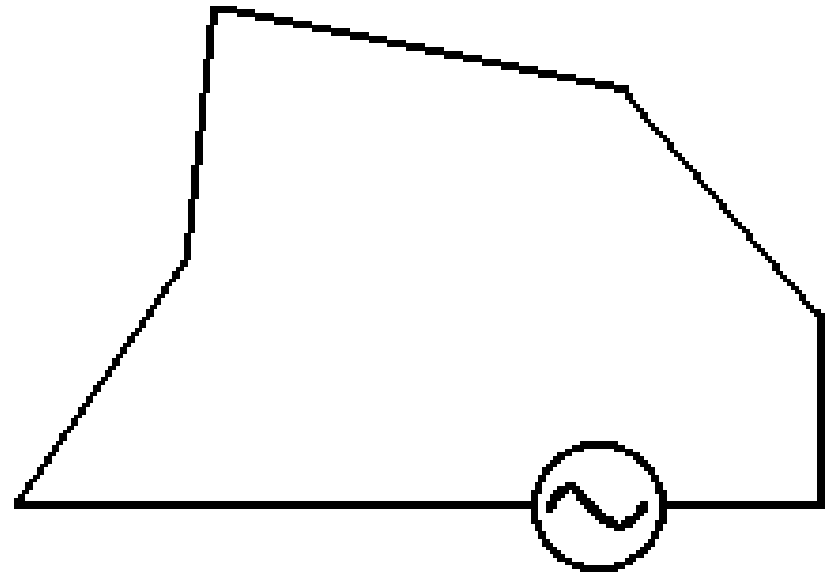


Basic Wire Antennas

Part II: Loops and Verticals

Loop Fundamentals

- **A loop antenna is composed of a single loop of wire, greater than a half wavelength long.**
- **The loop does not have to be any particular shape.**
- **RF power can be fed anywhere on the loop.**

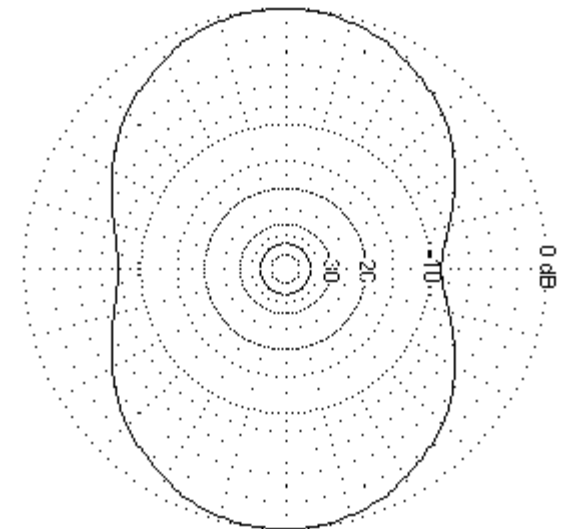
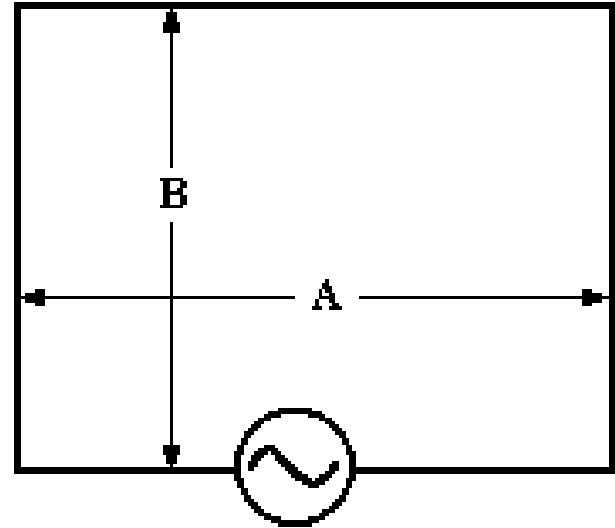


Loop Characteristics

- **Electrical length** - the overall length of the dipole in wavelengths at the frequency of interest.
- **Directivity** - the ratio of the maximum radiation of an antenna to the maximum radiation of a reference antenna. It is often measured in dBi, dB above an isotropic (non-directional) radiator.
- **Self Impedance** - the impedance at the antenna's feed point (not the feed point in the shack).
- **Radiation Resistance** - a fictitious resistance that represents power flowing out of the antenna
- **Radiation Pattern** - the intensity of the radiated RF as a function of direction.

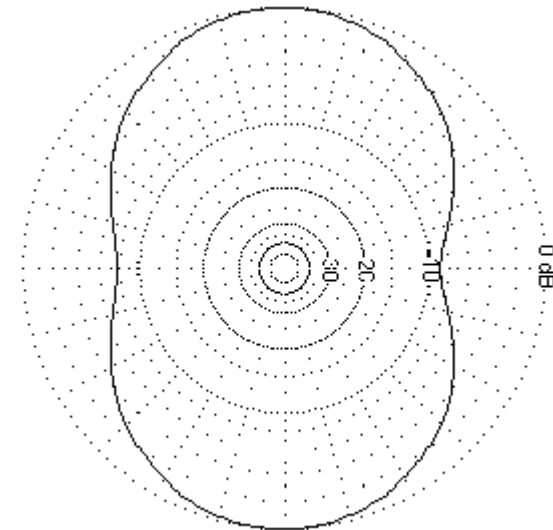
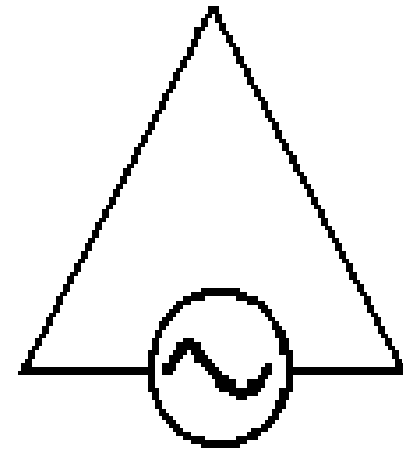
The Rectangular Loop

- The total length is approximately 1.02λ .
- The self impedance is $100 - 130 \Omega$ depending on height.
- The Aspect Ratio (A/B) should be between 0.5 and 2 in order to have $Z_s \sim 120 \Omega$.
- SWR bandwidth is $\sim 4.5\%$ of design frequency.
- Directivity is ~ 2.7 dBi. Note that the radiation pattern has no nulls. Max radiation is broadside to loop
- Antenna can be matched to 50Ω coax with $75 \Omega \lambda / 4$ matching section.



The Delta Loop

- A three sided loop is known as a delta loop.
- For best results, the lengths of the 3 sides should be approximately equal
- The self impedance is 90 - 110 Ω depending on height.
- Bandwidth ~ 4 %
- Directivity is ~2.7 dBi. Note that the radiation pattern has no nulls. Max radiation is broadside to loop.
- Antenna can be matched to 50 Ω coax with 75 Ω $\lambda/4$ matching section.

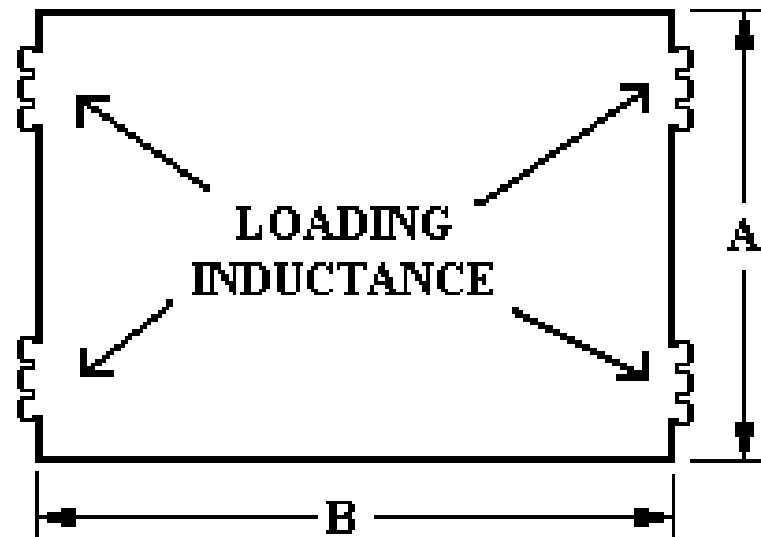


Design Table: Rectangular and Delta Loop

BAND	LENGTH OF ANTENNA (# 14 copper wire)	LENGTH OF MATCHING SECTION (RG-11 75 Ω VF = 0.66)
160 (1.83 MHz)	549 ft 4 in	88 ft 8 in
80 (3.6 MHz)	279 ft 2 in	45 ft 1 in
75 (3.9 MHz)	257 ft 8 in	41 ft 7 in
40 (7.1 MHz)	141 ft 7 in	22 ft 7 in
30	99 ft 1 in	16 ft 1 in
20	70 ft 9 in	11 ft 5 in
17	55 ft 6 in	8 ft 11 in
15	47 ft 4 in	7 ft 8 in
12	40 ft 4 in	6 ft 6 in
10 (28.4 MHz)	35 ft 5 in	5 ft 8 in

Reduced Size Loops

- **Loops for the low HF bands can be inconveniently large.**
- **Loading can be used to shorten the perimeter of the loop**
- **Directivity ~ 2 dBi**
- **SWR Bandwidth is ~ 2.5% of design frequency**
- **Radiation pattern is almost omnidirectional**
- **Input impedance is ~ 150 Ω .
Can be matched with 4:1 balun**



Design Table: Inductively Loaded Loop

BAND	LENGTH A	LENGTH B	LOADING INDUCTANCE (4)
160 (1.83 MHz)	60 ft 0 in	90 ft 0 in	63 μH
80 (3.6 MHz)	35 ft 6 in	45 ft 9 in	30 μH
75 (3.9 MHz)	28 ft 2 in	42 ft 3 in	27 μH
40 (7.1 MHz)	15 ft 5 in	23 ft 2 in	15 μH

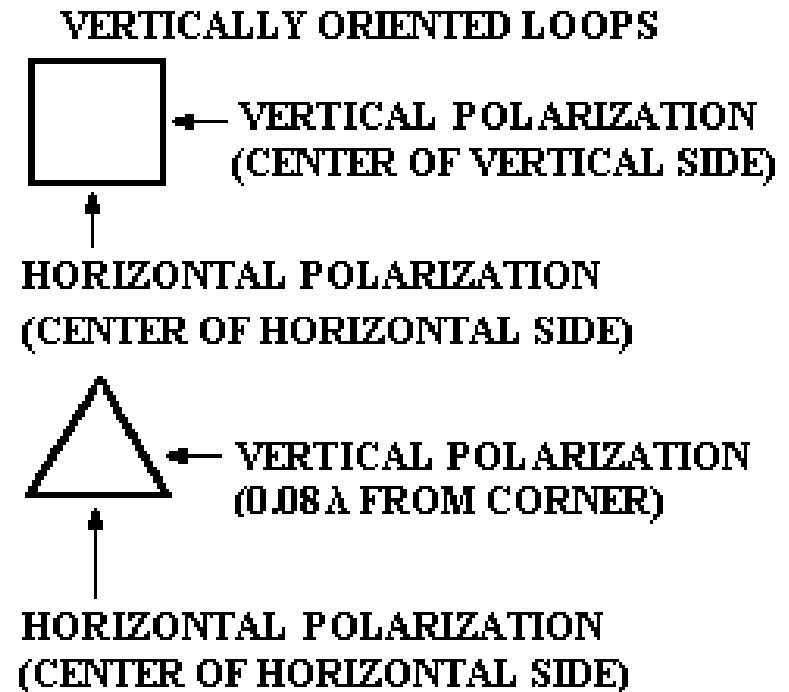
The loop is vertically oriented, with the lower wire approximately 10 feet above ground

Harmonic Operation of Loops

- **A loop antenna is also resonant at integral multiples of its resonant frequency.**
- **The self impedance of a $\lambda/2$ dipole at these multiples of the resonant frequency is 200 - 300 ohms.**
- **The directivity is lower on harmonic frequencies**
- **Vertically oriented loops will have high angles of radiation on harmonic frequencies.**
- **Horizontally oriented loops will have lower angles of radiation on harmonic frequencies.**

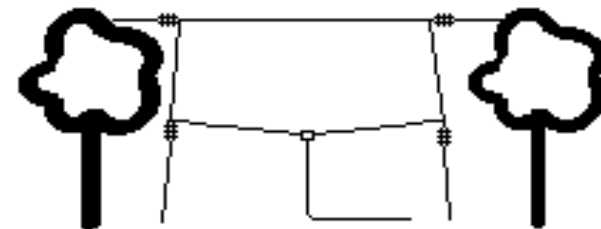
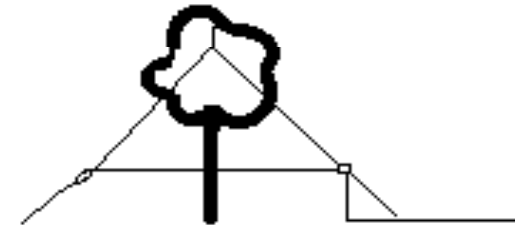
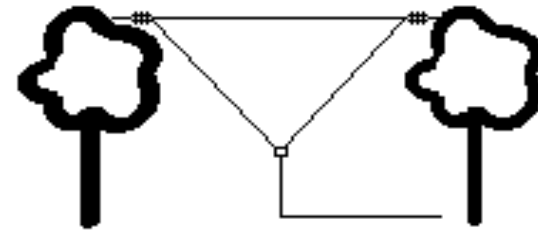
Polarization of Loop Antennas

- The RF polarization of a vertically oriented loop may be vertical or horizontal depending on feed position
- Horizontally polarized loops are predominantly horizontally polarized in all cases.
- Vertical polarization is preferred when antenna is low



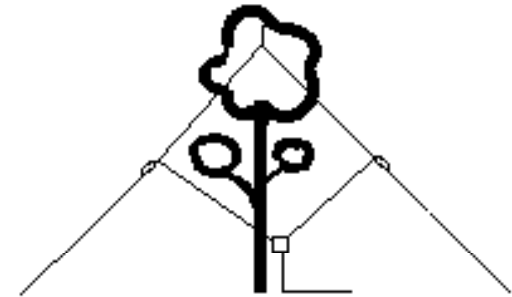
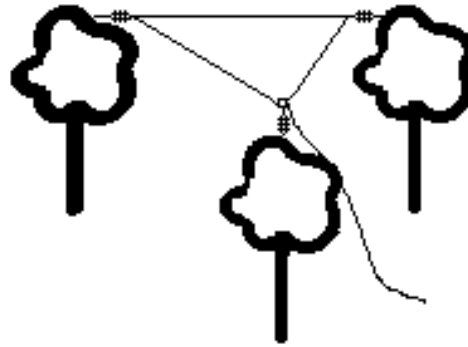
Putting up a loop

- Vertically oriented loops may be erected with one or between 2 supports
- A Horizontally oriented loop will require at least 3 supports
- When more than one support is used, they do not have to be exactly the same height

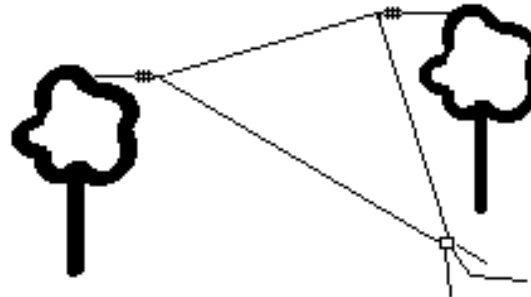


Putting up a loop

- The diagram at the lower left shows a sloping loop that uses only 2 supports



- Sloping loops radiate both horizontally and vertically polarized RF



Characteristics of Vertical Antennas

- **Electrical length** - the overall length of the antenna in wavelengths at the frequency of interest.
- **Radiation Angle** - the takeoff angle for which the radiation is maximum.
- **Self Impedance** - the impedance at the antenna's feed point (not the feed point in the shack).
- **Ground Loss Resistance** - a fictitious resistance that represents power lost in the ground system
- **Reflection Losses** - reduction in signal strength due to reflection of signals from the ground. (ground is a poor reflector for vertically polarized RF).

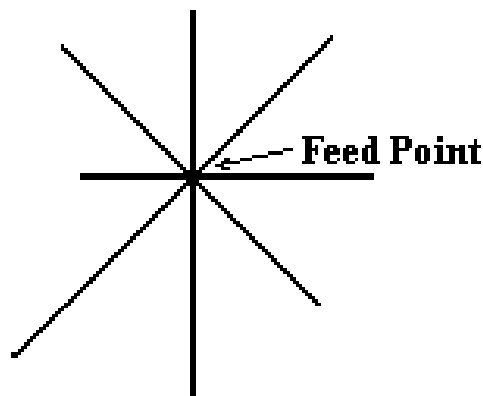
The Importance of the Ground

- **The ground is part of the vertical antenna, not just a reflector of RF, unless the antenna is far removed from earth (usually only true in the VHF region)**
- **RF currents flow in the ground in the vicinity of a vertical antenna. The region of high current is near the feed point for verticals less than $\lambda/4$ long, and is $\sim \lambda/3$ out from the feed point for a $\lambda/2$ vertical.**
- **To minimize losses, the conductivity of the ground in the high current zones must be very high.**
- **Ground conductivity can be improved by using a ground radial system, or by providing an artificial ground plane known as a counterpoise.**
- **Counterpoises are most practical in the VHF range. At HF, radial systems are generally used.**

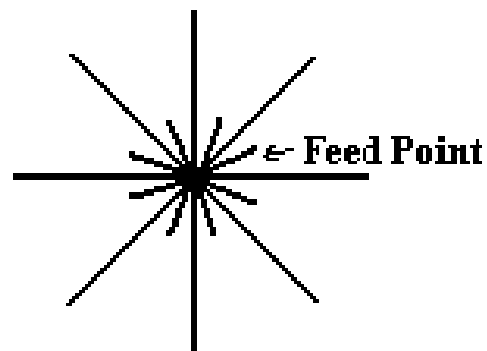
Notes on ground system construction

- **Ground radials can be made of almost any type of wire**
- **The radials do not have to be buried; they may lay on the ground**
- **The radials should extend from the feed point like spokes of a wheel**
- **The length of the radials is not critical. They are not resonant. They should be as long as possible**
- **For small radial systems ($N < 16$) the radials need only be $\lambda/8$ long. For large ground systems ($N > 64$) the length should be $\sim \lambda/4$**
- **Elevated counterpoise wires are usually $\lambda/4$ long**

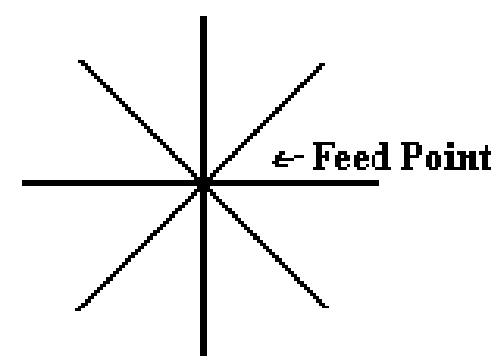
Radial/Counterpoise Layout



**Ground Radial System
with random length
radials on ground**



**Ground Radial System
with extra short radials
in high current region**



**Elevated Counterpoise
using $\lambda/4$ radials**

- **Note: The radials used in a counterpoise are not grounded !!**

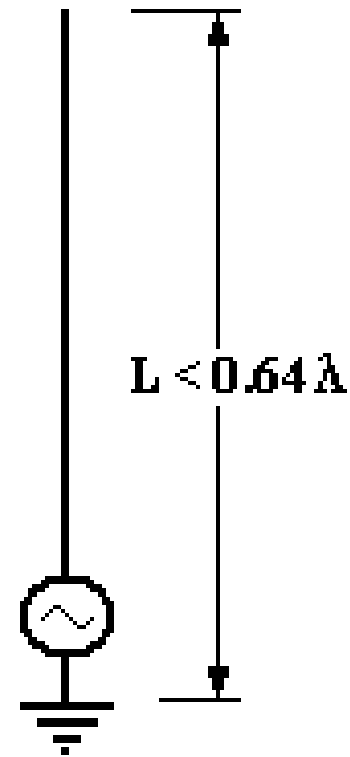
Design Table: Ground Radials for $\lambda /4$ Vertical Monopole

No OF RADIALS	LENGTH OF RADIALS (in wavelengths)	GROUND RESISTANCE (ohms)
4	0.0625	28
8	0.08	20
16	0.10	16
24	0.125	10
36	0.15	7
60	0.2	4
90	0.25	1
120	0.40	<<1

- **Radial wires may be in contact with earth or insulated**
- **Wire gauge is not important; small gauge wire such as #24 may be**
- **The radial system may be elevated above the earth (this is known as a counterpoise system)**

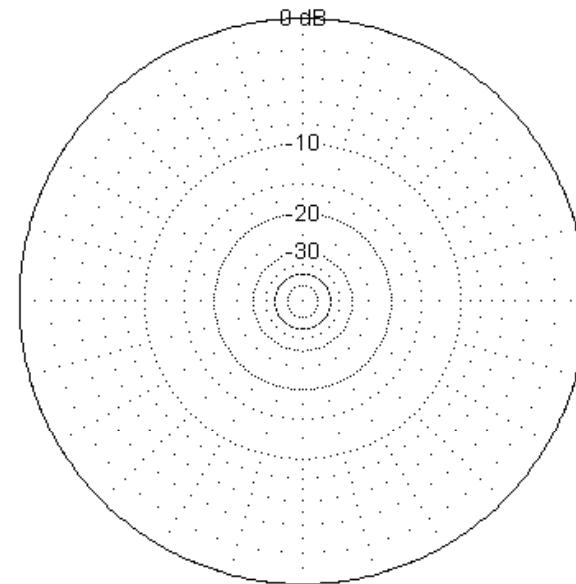
Vertical Monopole Antennas

- **Length $< 0.64\lambda$**
- **Self impedance:**
 $Z_S = Z_{ANT} + R_{GND} + R_{REF}$
- **Efficiency:**
 $\eta = |Z_{ANT}| / |Z_S|$ η ranges from $< 1\%$ to $> 80\%$ depending on antenna length and ground system
- **Efficiency improves as monopole gets longer and ground losses are reduced**

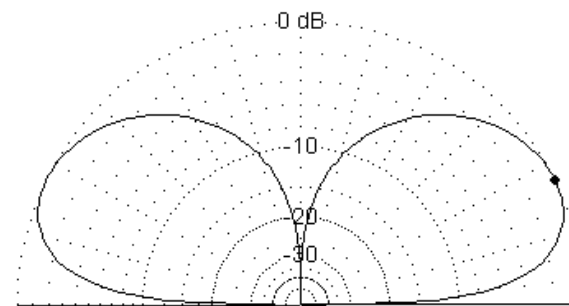


$\lambda / 4$ Vertical Monopole

- Length $\sim 0.25\lambda$
- Self impedance:
 $Z_S \sim 36 - 70 \Omega$
- The $\lambda / 4$ vertical requires a ground system, which acts as a return for ground currents. The “image” of the monopole in the ground provides the “other half” of the antenna
- The length of the radials depends on how many there are
- Take off angle ~ 25 deg



Azimuth Plot



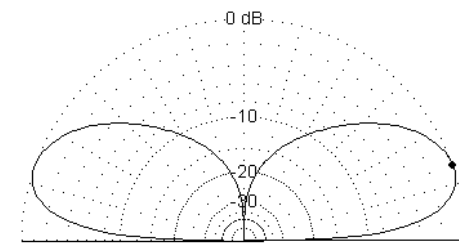
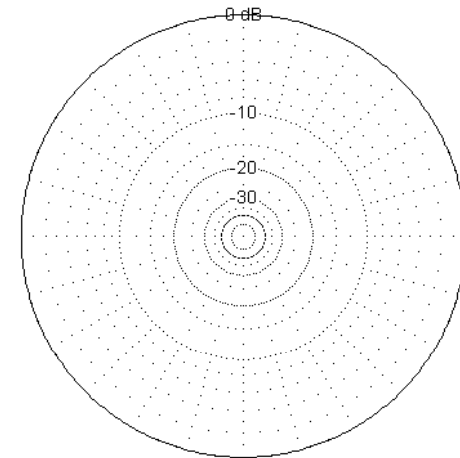
Elevation Plot

Design Table: $\lambda / 4$ Vertical Monopole

BAND	LENGTH OF MONOPOLE (#14 wire)
160 (1.83 MHz)	127 ft 10 in
80 (3.60 MHz)	65 ft 0 in
75 (3.90 MHz)	60 ft 0 in
40 (7.10 MHz)	33 ft 0 in
30	23 ft 1 in
20	16 ft 6 in
17	12 ft 11 in
15	11 ft 0 in
12	9 ft 5 in
10 (28.4 MHz)	8 ft 3 in

$\lambda / 2$ Vertical Monopole

- Length is approximately 0.48λ
- Self impedance $\sim 2000 \Omega$
- Antenna can be matched to 50 ohm coax with a tapped tank circuit
- Take off angle ~ 15 deg
- Ground currents at base of antenna are small; radials are less critical for $\lambda/2$ vertical

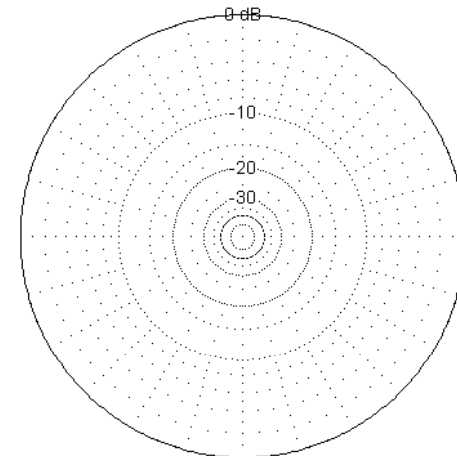


Design Table: $\lambda/2$ Vertical

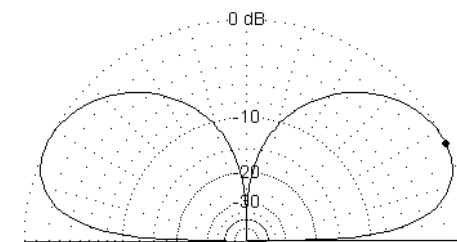
BAND	LENGTH OF MONOPOLE (#14 wire)
160 (1.83 MHz)	255 ft 8 in
80 (3.60 MHz)	130 ft 0 in
75 (3.90 MHz)	120 ft 0 in
40 (7.10 MHz)	66 ft 0 in
30	46 ft 2 in
20	33 ft 0 in
17	25 ft 10 in
15	22 ft 0 in
12	19 ft 0 in
10 (28.4 MHz)	16 ft 6 in

Short Vertical Monopoles

- It is not possible for most amateurs to erect a $\lambda/4$ or $\lambda/2$ vertical on 80 or 160 meters
- The monopole, like the dipole can be shortened and resonated with a loading coil
- The feed point impedance can be quite low ($\sim 10 \Omega$) with a good ground system, so an additional matching network is required
- Best results are obtained when loading coil is at the center



Azimuth Plot



Elevation Plot

Design Table: Short($\lambda/8$) Vertical Monopoles

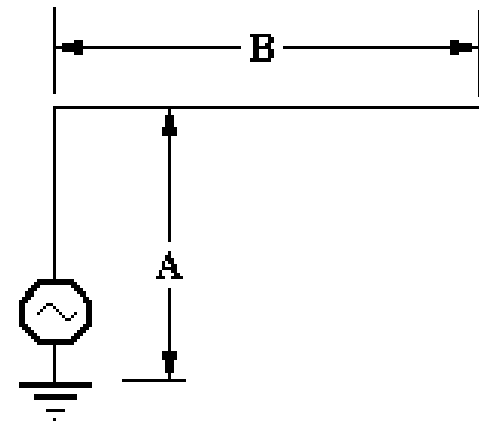
BAND	LENGTH OF MONOPOLE (#14 wire)
160 (1.83 MHz)	67 ft 2 in
80 (3.60 MHz)	34 ft 2 in
75 (3.90 MHz)	31 ft 6 in
40 (7.10 MHz)	17 ft 4 in

For base loading an inductive reactance of $j550 \Omega$ is req'd

For center loading and inductive reactance of $j1065 \Omega$ is req'd

Inverted L

- The inverted L is a vertical monopole that has been folded so that a portion runs horizontally
- Typically the overall length is $\sim 0.3125\lambda$ and the vertical portion is $\sim 0.125\lambda$ long
- Self impedance is $\sim 50 + j200\Omega$
- Series capacitor can be used to match antenna to coax



Design Table: Inverted L

BAND	LENGTH A	LENGTH B	MATCHING CAPACITANCE
160 (1.83 MHz)	67 ft 2 in	100 ft 9 in	410 pF
80 (3.6 MHz)	34 ft 2 in	51 ft 3 in	220 pF
75 (3.9 MHz)	31 ft 6 in	47 ft 3 in	200 pF
40 (7.1 MHz)	17 ft 3 in	26 ft 0 in	110 pF

Use of a Vertical Monopole on several bands

- **If a low angle of radiation is desired, a vertical antenna can be used on any frequency where it is shorter than 0.64λ :**
- **The lower frequency limit is set by the capability of the matching network and by efficiency constraints.**
- **The ground system should be designed to accommodate the lowest frequency to be used. Under normal circumstances, this will be adequate at higher frequencies**

Loop and Vertical Antenna Materials

- **Wire**
 - **#14 Copperweld**
 - very strong
 - kinks very easily; it is difficult to work with
 - does not stretch
 - subject to corrosion
 - **#14 stranded copper wire with vinyl insulation**
 - moderately strong
 - easy to work with, does not kink
 - can stretch under high tension (a problem with long antennas)
 - does not corrode
 - **Monel trolling wire**
 - strong
 - much higher resistivity than copper
 - corrosion resistant

Loop and Vertical Antenna Materials

- **Insulators**
 - **ceramic**
 - **strong**
 - **resist very high voltages**
 - **not affected by sunlight**
 - **expensive**
 - **plastic**
 - **weaker than ceramic insulators**
 - **resist moderately high voltages**
 - **can be degraded by sunlight**
 - **relatively inexpensive**

Dipole Antenna Materials

- **Baluns**

- choke balun (several turns of coax wound into coil ~ 6 in in dia) is usually sufficient unless impedance transformation is required
- Powdered-iron core baluns should be used within their ratings to avoid core saturation.

- **Support ropes**

- should be at least 3/16 inch diameter and UV stabilized
- UV stabilized Dacron works well in most applications
- polyolefin ropes quickly degrade in sunlight and should be avoided

Loop/Vertical Antenna Supports

- **Almost any structure can be used to support a loop or vertical**
- **A loop antenna should be kept at least 12 inches away from a conducting support and a vertical antenna should not be run parallel to a conducting support**
- **If trees are used, leave some slack in the antenna so that swaying of the branches does not snap the wire**
- **If a tree is used to support a vertical antenna, the wire should not run straight down the trunk. The wire can be run 10 - 20 degrees from vertical without problems**
- **The top wire of a horizontally polarized vertically oriented loop should be at least $1/2$ wavelength about the surrounding terrain ($\lambda/2 = 492/f$)**

Other useful information

- **Do not run a loop or inverted L above power lines!!!!**
- **When the feed line leaves the loop, it should run perpendicular to it for at least 1/4 wavelength**
- **If an elevated counterpoise is used for a vertical antenna, place it high enough that it people cannot touch it**
- **If a loop antenna's lower wire has to be close to the ground, place it high enough that no one will tamper with it**

Antenna Comparison

ANTENNA	GAIN (dBi)	Pros	Cons
1λ loop	2.7	Good gain	Can be very large on low HF bands
“Small Loop”	2	Smaller than equivalent 1λ loop	Low gain and 4 loading coils are required
$\lambda/4$ vertical	< 0	Simple to erect	Radials or counterpoise required
$\lambda/2$ vertical	<1	More gain, less affected by ground	High support and complex matching network required
Short Vertical	< -1	Shorter support needed	Generally lossy ; good ground system required