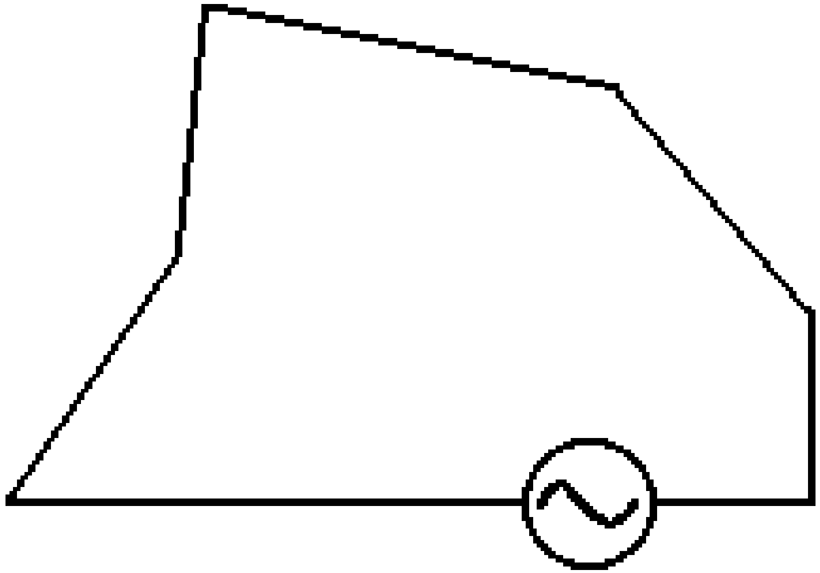
Basic Wire Antennas

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.

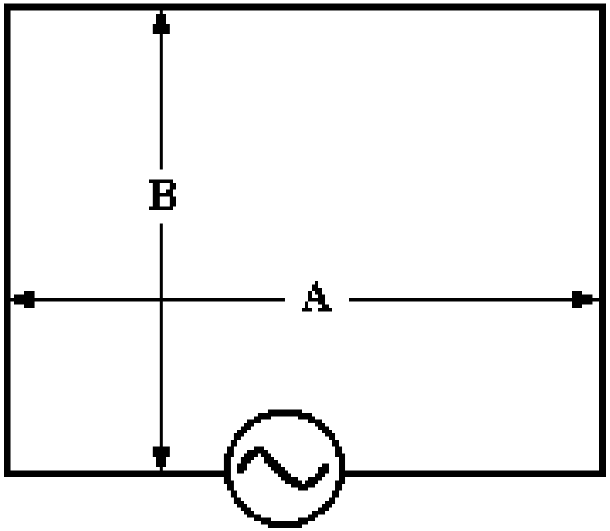


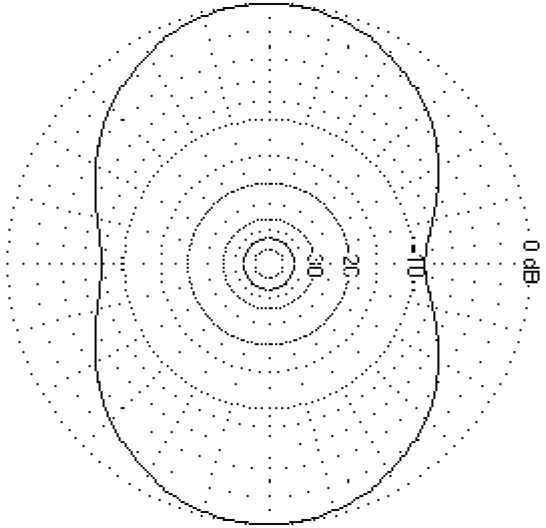
Loop Characteristics

- **Electrical length - the overall length of the dipole in <u>wavelengths</u> 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

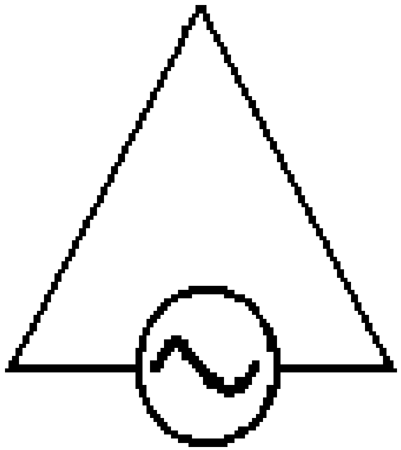
- The total length is approximately 1.02 λ.
- The self impedance is 100 - 130 Ω depending on height.
- The Aspect Ratio (A/B) should be between 0.5 and 2 in order to have Z_s ~ 120 Ω.
- SWR bandwidth is ~ 4.5% of design frequency.
- Directivity is ~2.7 dBi. Note that the radiation pattern has no nulls.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

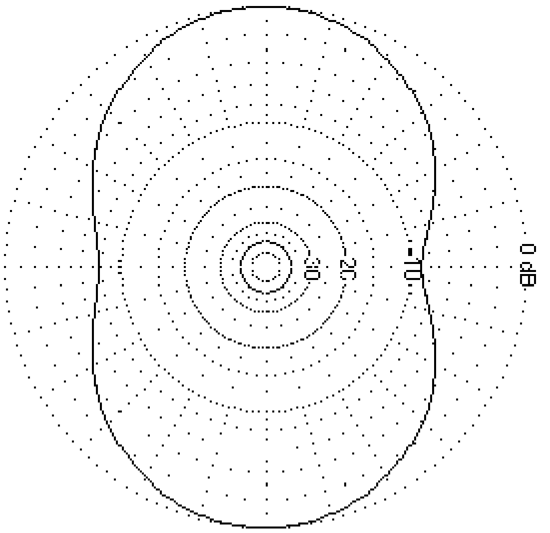




The Delta Loop

- 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 λ /4 matching section.



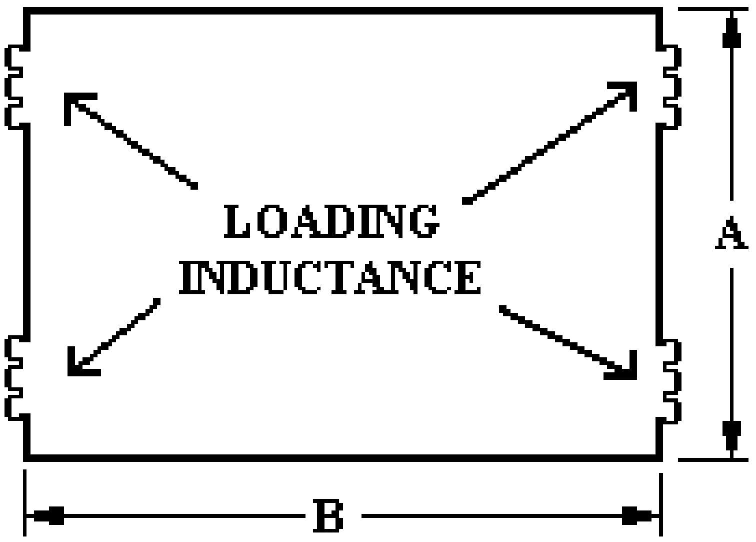


Design Table: Rectangular and Delta Loop

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 µ H
80 (3.6 MHz)	35 ft 6 in	45 ft 9 in	30 µ H
75 (3.9 MHz)	28 ft 2 in	42 ft 3 in	27 µ H
40 (7.1 MHz)	15 ft 5 in	23 ft 2 in	15 µ H

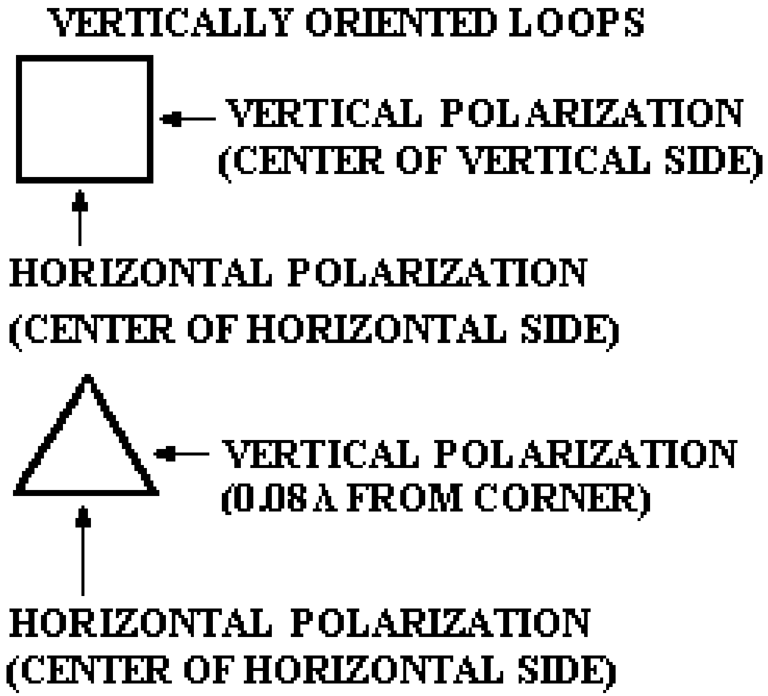
The loop is vertically oriented, with the lower wire approximately 10 feet above ground

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.

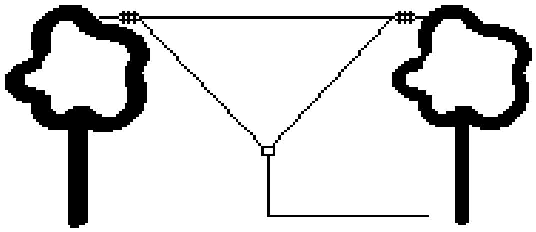
Polarization of Loop Antennas

- 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

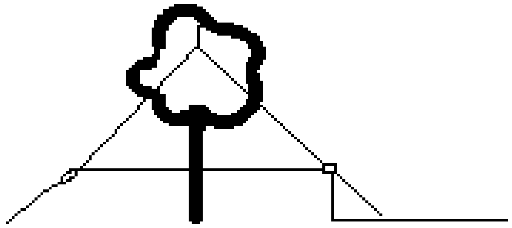


Putting up a loop

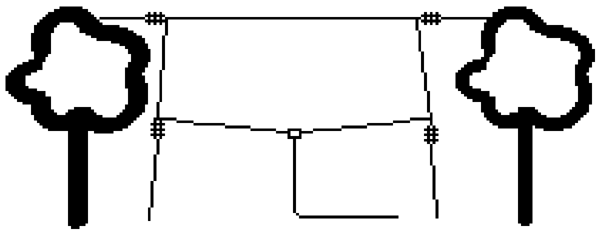
- Vertically oriented loops may be erected with one or between 2 supports



- A Horizontally oriented loop will require at least 3 supports

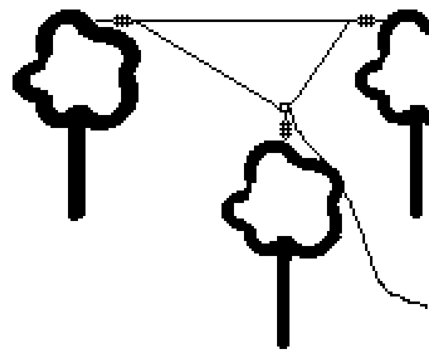


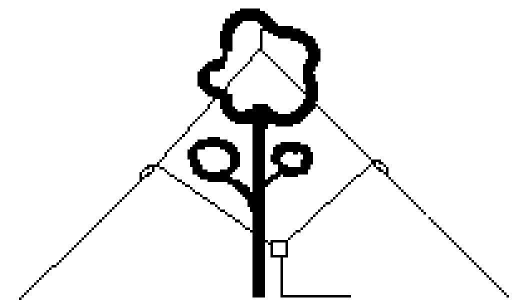
- When more than one support is used, they do not have to be exactly the same height

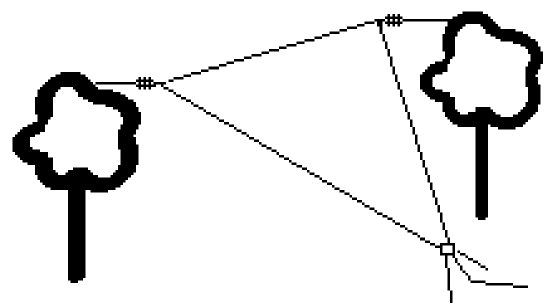


Putting up a loop

- 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).**

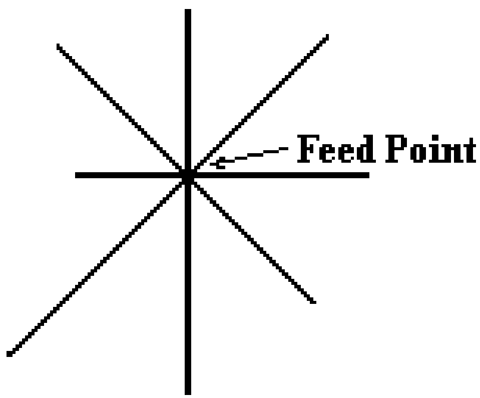
The Importance of the Ground

- 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 that $\lambda/4$ long, and is ~ $\lambda/3$ 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.

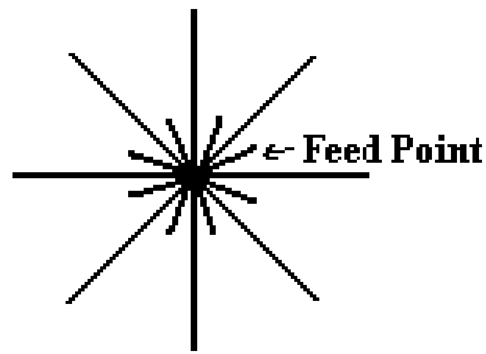
Notes on ground system construction

- **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**

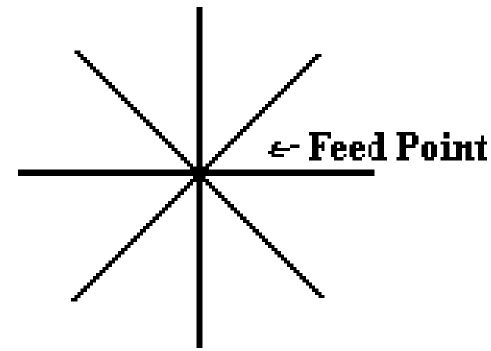
Radial/Counterpoise Layout



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 !!**

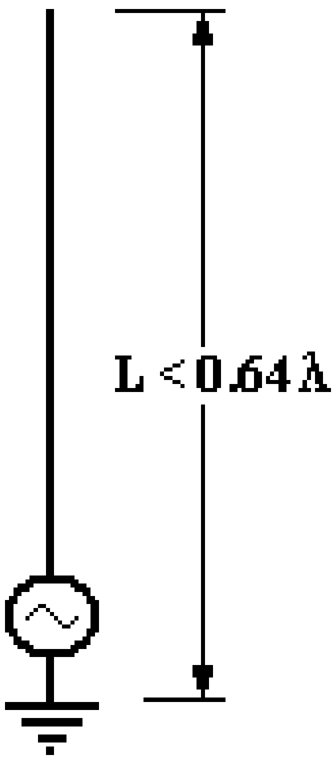
Design Table: Ground Radials for λ /4 Vertical Monopole

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)**

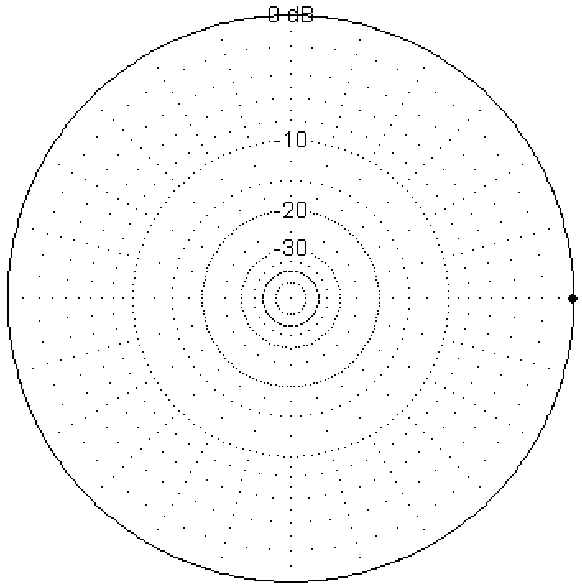
Vertical Monopole Antennas

- Length < 0.64λ
- 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

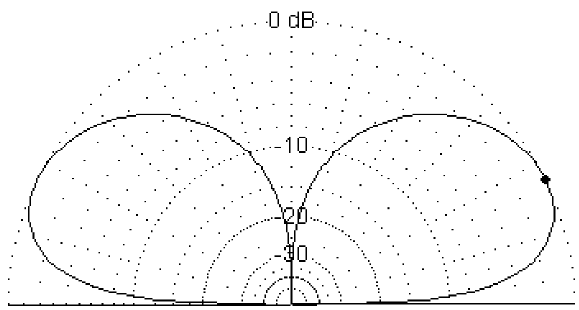


λ /4 Vertical Monopole

- Length ~ 0.25λ
- Self impedance:
  Z_S ~ 36 - 70 Ω
- The λ /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



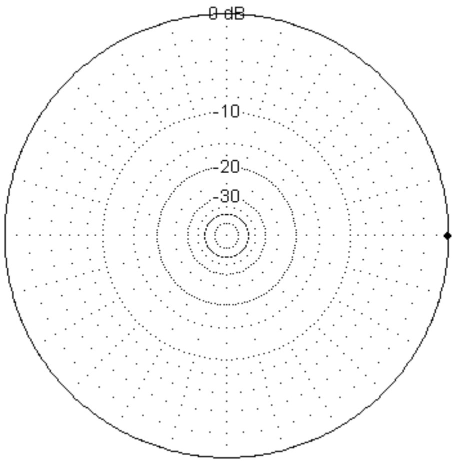
Elevation Plot

Design Table: λ /4 Vertical Monopole

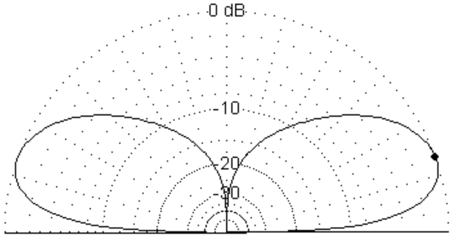
BAND	LENGTH OF MONOPOLE (#14 wire)
160 (1.83 MHz)	127 ft 10 in
80 (3.60 MHz)	65 ft 0 in
75 (3.90 MHz)	60 ft 0 in
40 (7.10 MHz)	33 ft 0 in
30	23 ft 1 in
20	16 ft 6 in
17	12 ft 11 in
15	11 ft 0 in
12	9 ft 5 in
10 (28.4 MHz)	8 ft 3 in

λ /2 Vertical Monopole

- **Length is approximately 0.48λ**
- **Self impedance ~ 2000 Ω**
- **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 λ/2 vertical**



Azimuth Plot



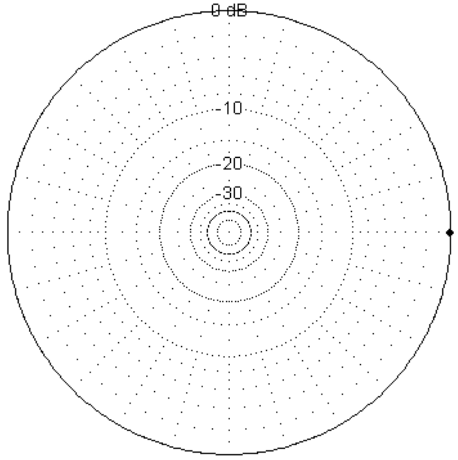
Elevation Plot

Design Table: $\lambda/2$ Vertical

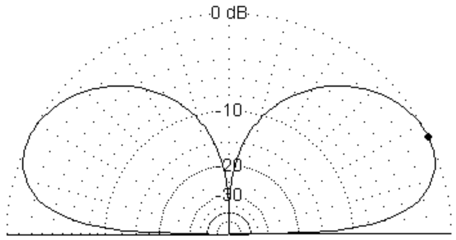
BAND	LENGTH OF MONOPOLE (#14 wire)
160 (1.83 MHz)	255 ft 8 in
80 (3.60 MHz)	130 ft 0 in
75 (3.90 MHz)	120 ft 0 in
40 (7.10 MHz)	66 ft 0 in
30	46 ft 2 in
20	33 ft 0 in
17	25 ft 10 in
15	22 ft 0 in
12	19 ft 0 in
10 (28.4 MHz)	16 ft 6 in

Short Vertical Monopoles

- It is not possible for most amateurs to erect a λ/4 or λ/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 (~10 Ω) 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

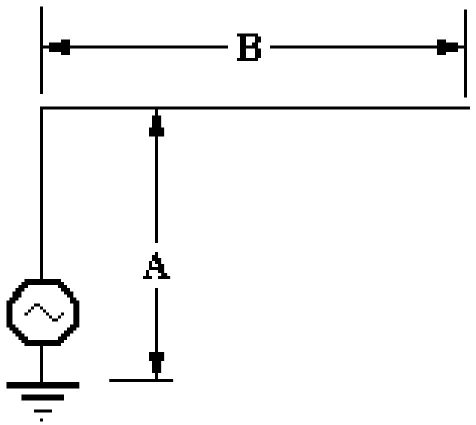
Design Table: Short(λ/8) Vertical Monopoles

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 Ω is req'd
For center loading and inductive reactance of j1065 Ω 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 ~ 0.3125λ and the vertical portion is ~ 0.125λ long
- Self impedance is ~ 50 + j200Ω
- 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 is is shorter than 0.64 λ :**
- **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 resitivity 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
λ/4 vertical	< 0	Simple to erect	Radials or counterpoise required
λ/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