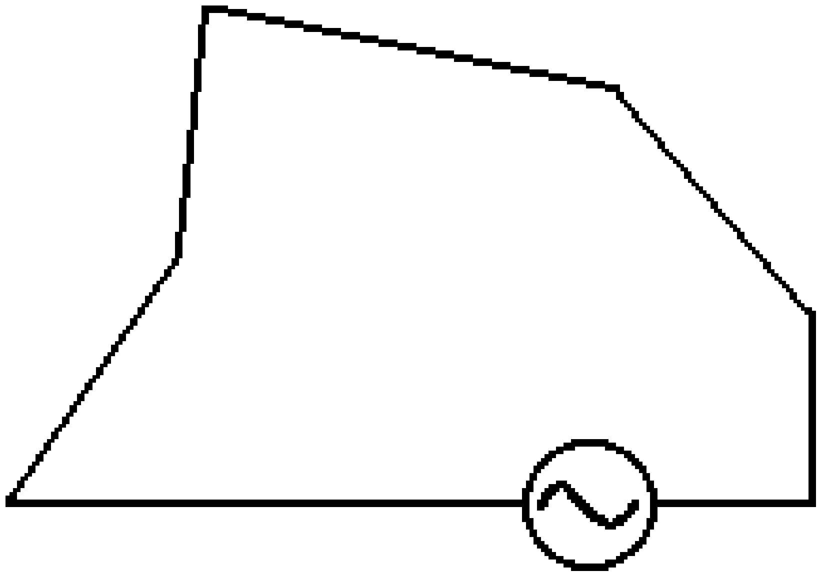
Basic Wire Antennas

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.

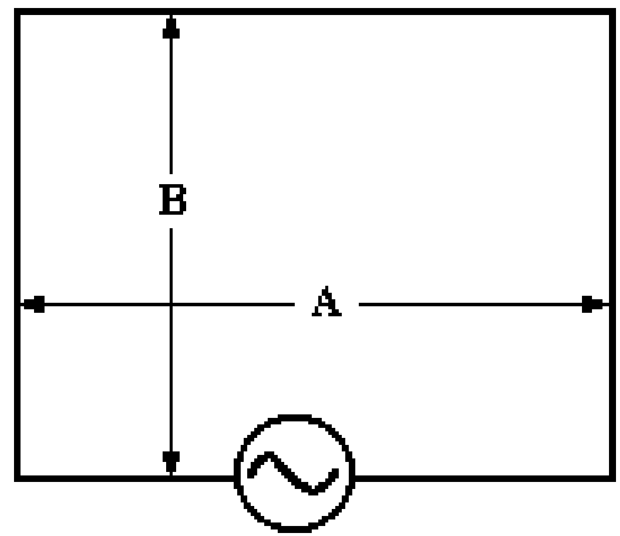


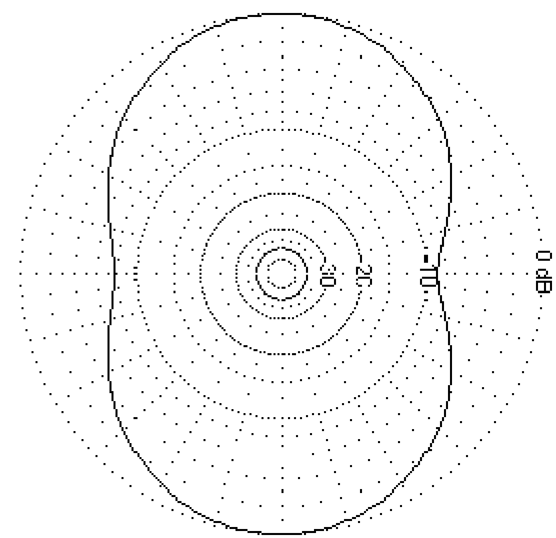
Loop Characteristics

- 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

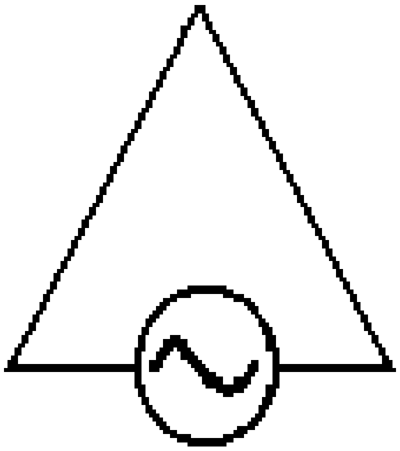
- The total length is approximately 1.02 λ.
- The self impedance is 100 - 130 Ω depending on height.
- The Aspect Ratio (A/B) should be between 0.5 and 2 in order to hav Z_s ~ 120 Ω.
- SWR bandwidth is ~ 4.5% of design frequency.
- Directivity is ~2.7 dBi. Note that the radiation pattern has no nulls.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

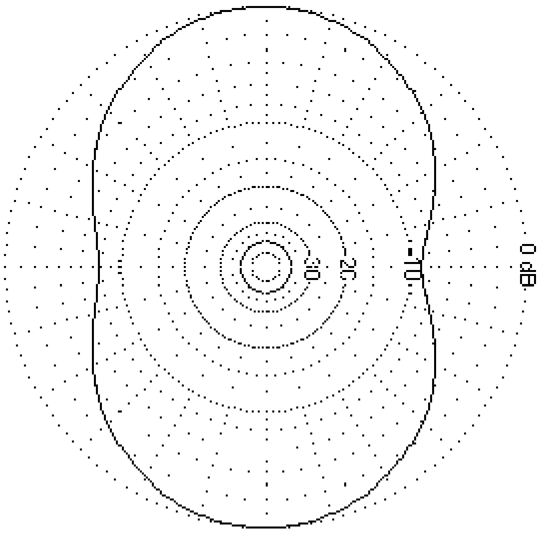




The Delta Loop

- 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.



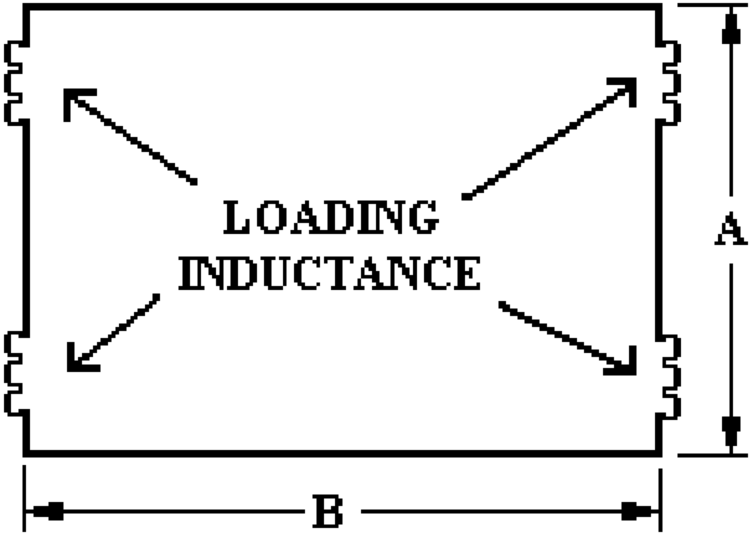


Design Table: Rectangular and Delta Loop

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

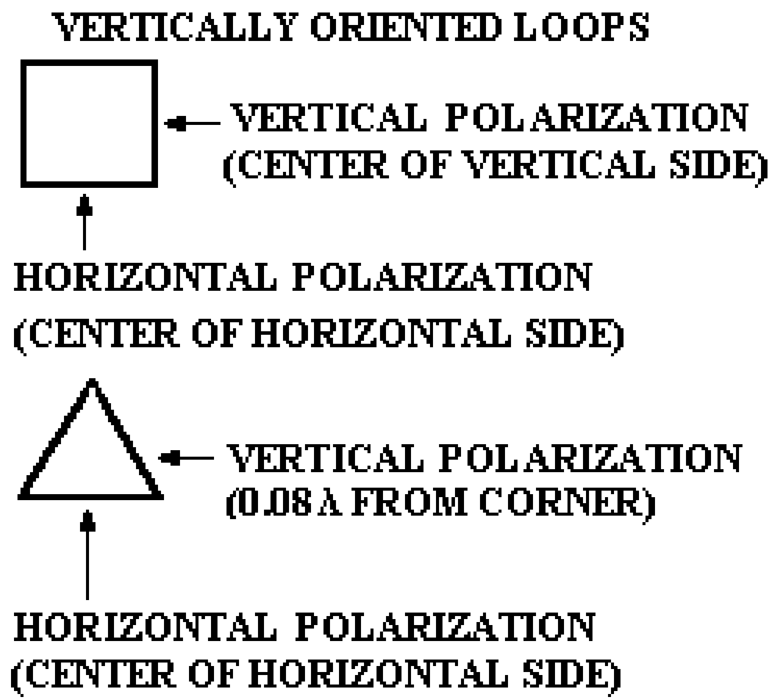
The loop is vertically oriented, with the lower wire approximately 10 feet above ground

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.**

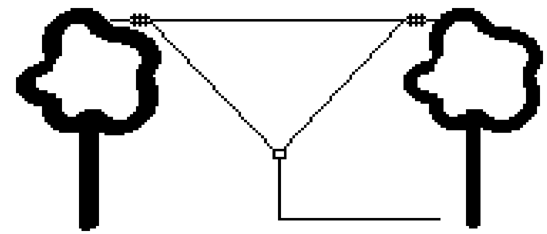
Polarization of Loop Antennas

- 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

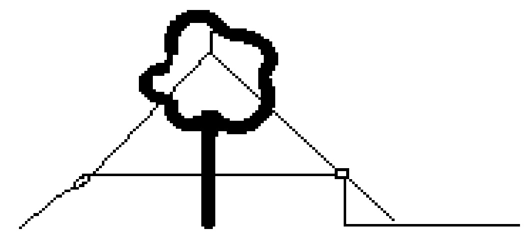


Putting up a loop

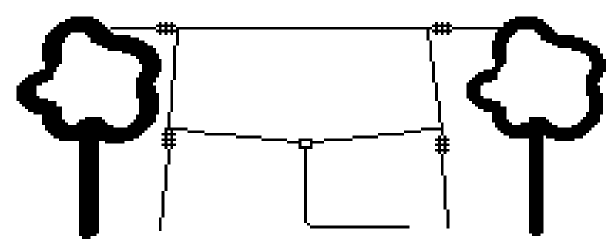
- Vertically oriented loops may be erected with one or between 2 supports



- A Horizontally oriented loop will require at least 3 supports

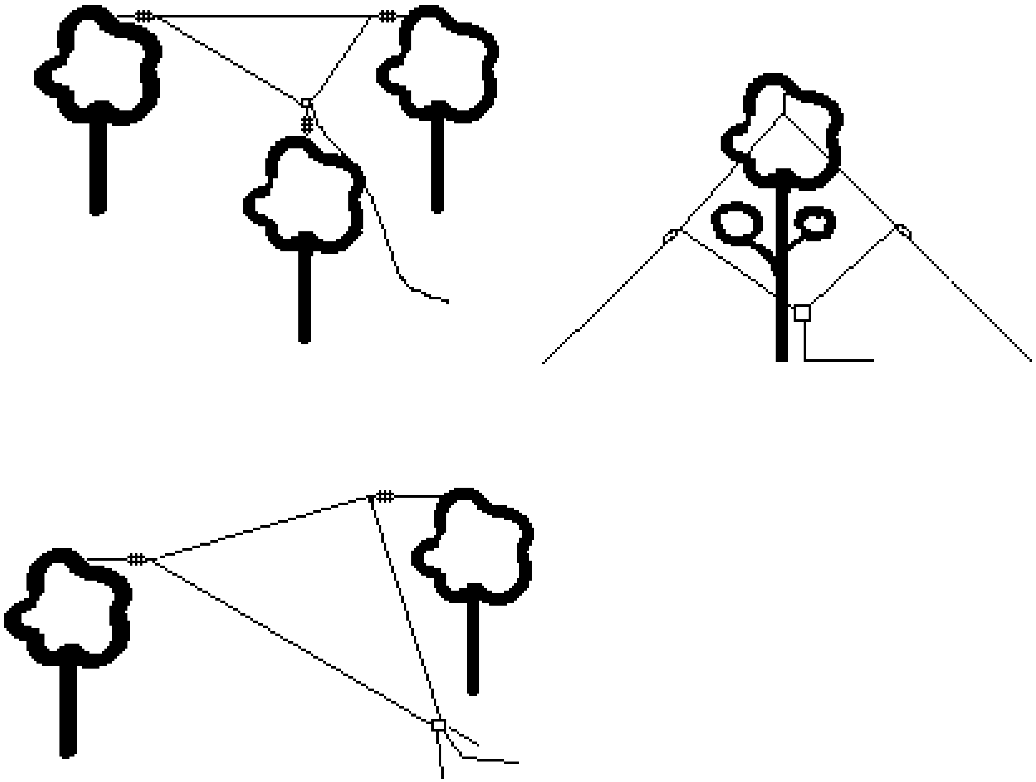


- When more than one support is used, they do not have to be exactly the same height



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).**

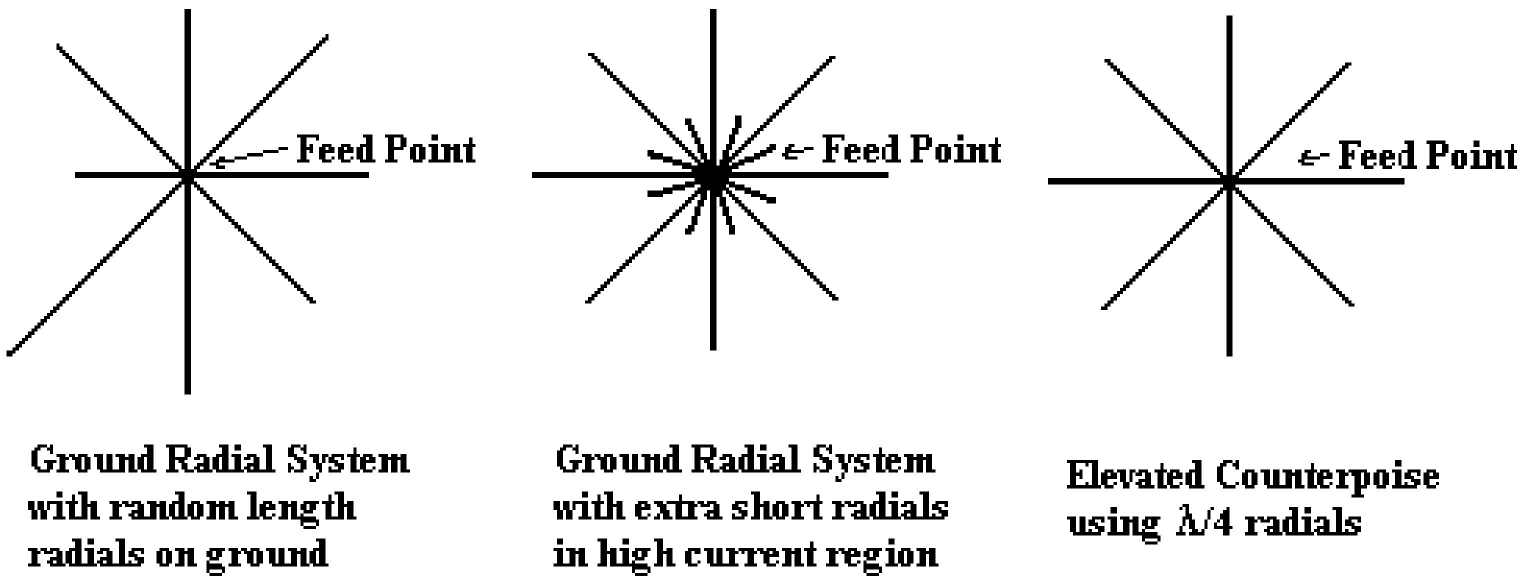
The Importance of the Ground

- 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 $\sim \lambda/3$ 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



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

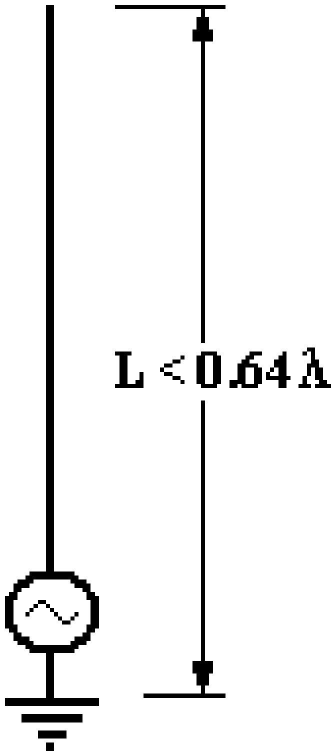
Design Table: Ground Radials for λ /4 Vertical Monopole

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)**

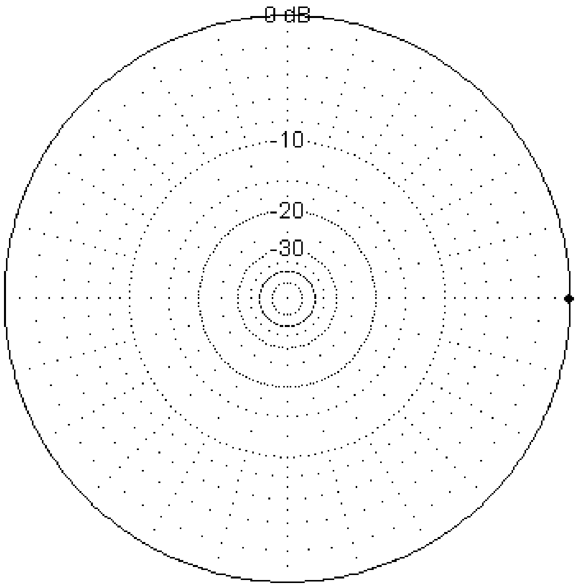
Vertical Monopole Antennas

- **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**

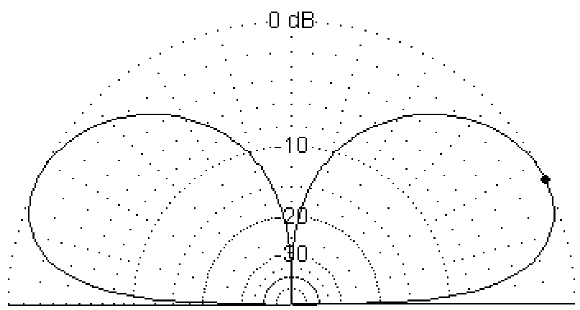


λ /4 Vertical Monopole

- 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



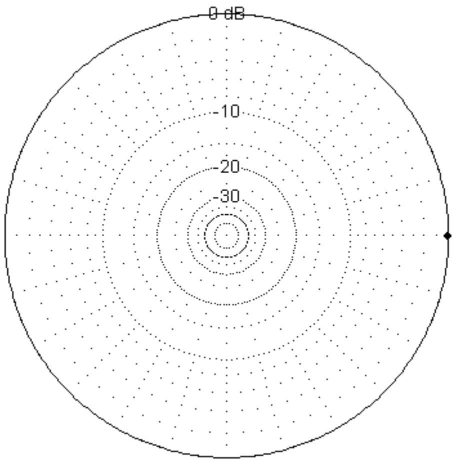
Elevation Plot

Design Table: λ /4 Vertical Monopole

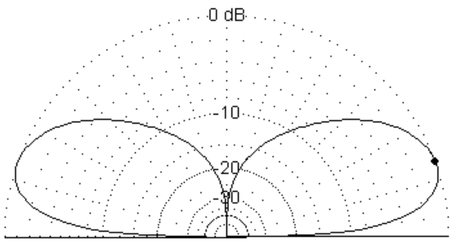
BAND	LENGTH OF MONOPOLE (#14 wire)
160 (1.83 MHz)	127 ft 10 in
80 (3.60 MHz)	65 ft 0 in
75 (3.90 MHz)	60 ft 0 in
40 (7.10 MHz)	33 ft 0 in
30	23 ft 1 in
20	16 ft 6 in
17	12 ft 11 in
15	11 ft 0 in
12	9 ft 5 in
10 (28.4 MHz)	8 ft 3 in

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



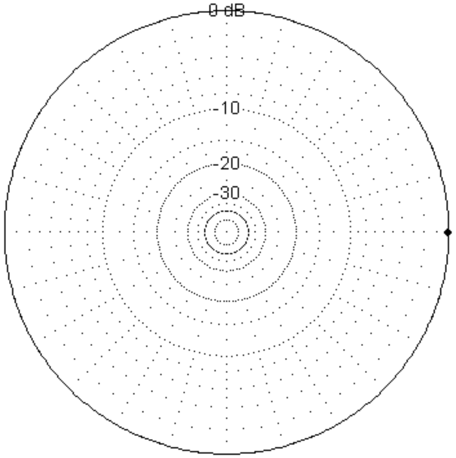
Elevation Plot

Design Table: λ/2 Vertical

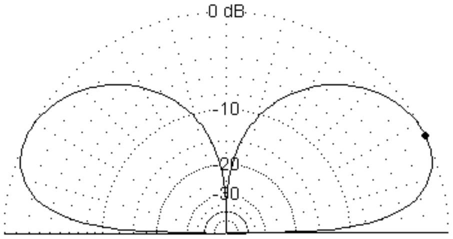
BAND	LENGTH OF MONOPOLE (#14 wire)
160 (1.83 MHz)	255 ft 8 in
80 (3.60 MHz)	130 ft 0 in
75 (3.90 MHz)	120 ft 0 in
40 (7.10 MHz)	66 ft 0 in
30	46 ft 2 in
20	33 ft 0 in
17	25 ft 10 in
15	22 ft 0 in
12	19 ft 0 in
10 (28.4 MHz)	16 ft 6 in

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

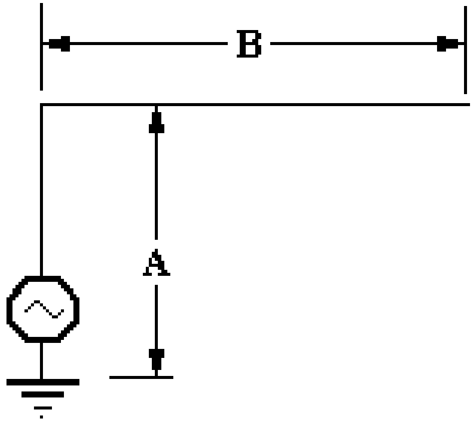
Design Table: Short(λ/8) Vertical Monopoles

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