Fundamentals of Wire Antennas

Dipoles, Loops and Verticals

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What is an antenna?

- An antenna is a device that:
  - Converts RF power applied to its feed point into electromagnetic radiation.
  - Intercepts energy from passing electromagnetic radiation, which then appears as RF voltage across the antenna's feed point.
- Any conductor, through which an RF current is flowing, can be an antenna.
- Any conductor that can intercept an RF field can be an antenna.
- Antennas do NOT have to be resonant to be highly efficient

Antenna Parameters

- Directivity or Gain:
  - Is the ratio of the power radiated by an antenna in its direction of maximum radiation to the power radiated by a reference antenna in the same direction.
  - Is measured in dBi (dB referenced to an isotropic antenna) or dBd (dB referenced to a half wavelength dipole)
- Feed point impedance (also called input or drive impedance):
  - Is the impedance measured at the input to the antenna.
  - The real part of this impedance is the sum of the radiation and loss resistances
  - The imaginary part of this impedance represents reactive power temporarily stored by the antenna.
- Bandwidth
  - Is the range of frequencies over which one or more antenna parameters stay within a certain range.
  - The most common bandwidth used is the one over which the SWR < 2:1 (9% reflected power)

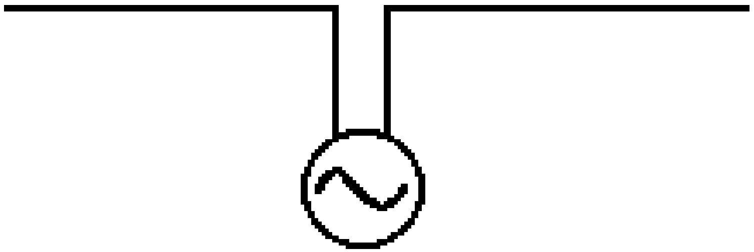
Antennas and Fields

- **Reciprocity Theorem:**
  - An antenna's properties are the same, whether it is used for transmitting or receiving.
- **The Near Field**
  - An electromagnetic field that exists within ~ 10λ of the antenna.
- **The Far Field**
  - An electromagnetic field launched by the antenna that extends throughout all space. This field transports power and is related to the aperture size radiation resistance of the antenna.

The Hertz Antenna (Dipole)

Dipole Fundamentals

- A dipole is antenna composed of a single radiating element split into two sections, not necessarily of equal length.
- The RF power is fed into the split.
- The radiators do not have to be straight.

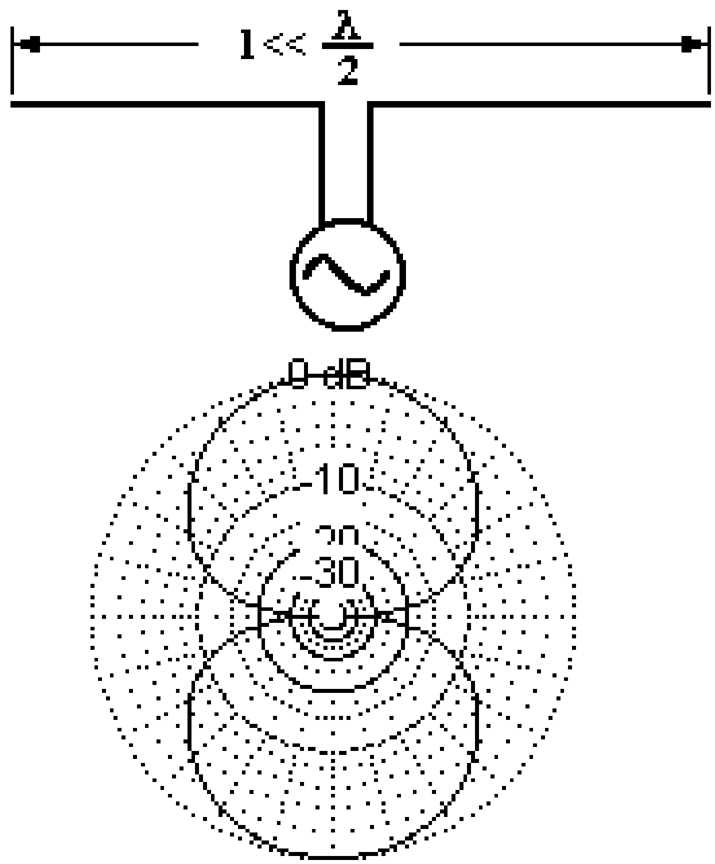


Dipole Characteristics

- 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 virtual resistance that represents power flowing out of the antenna into the free space impedance
- Radiation Pattern - the intensity of the radiated RF as a function of direction.

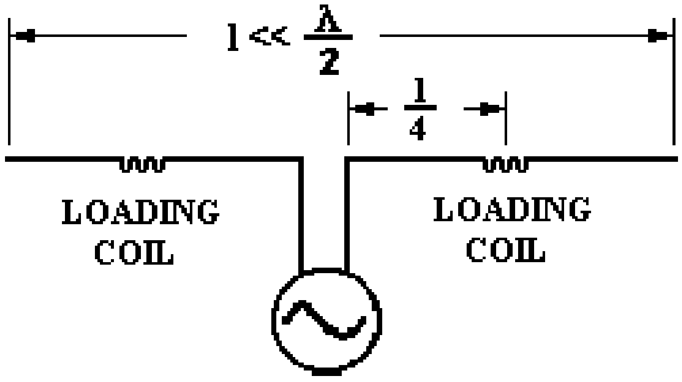
The Short Dipole

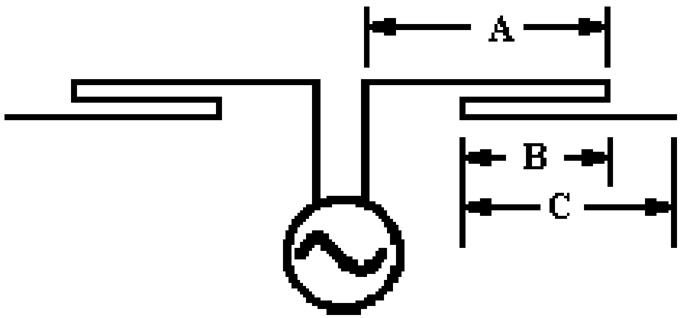
- The length is less than λ/2.
- The self impedance is generally capacitive.
- The radiation resistance is quite small and ohmic losses in antenna are high
- SWR bandwidth is quite small, ~ 2% of design frequency.
- Directivity is ~1.8 dBi. Radiation pattern resembles a figure 8



The Short Dipole

- For dipoles longer than λ/5, the antenna can be matched to coax by using loading coils
- For best results, the coils are placed in the middle of each leg of the dipole
- Loading coils can introduce additional loss of 1 dB or more due to wire resistance
- For dipoles longer than λ/3 the antenna can be matched to coax by using linear loading





Design Table: Short Dipole

λ/4 dipole with inductive loading

BAND	LENGTH OF ANTENNA (# 14 copper wire)	INDUCTANCE OF THE LOADING COIL (μH)
160 (1.83 MHz)	133 ft 10 in	90.0
80 (3.6 MHz)	67 ft 2 in	43.1
75 (3.9 MHz)	62 ft 0 in	39.4
40 (7.1 MHz)	34 ft 0 in	20.2

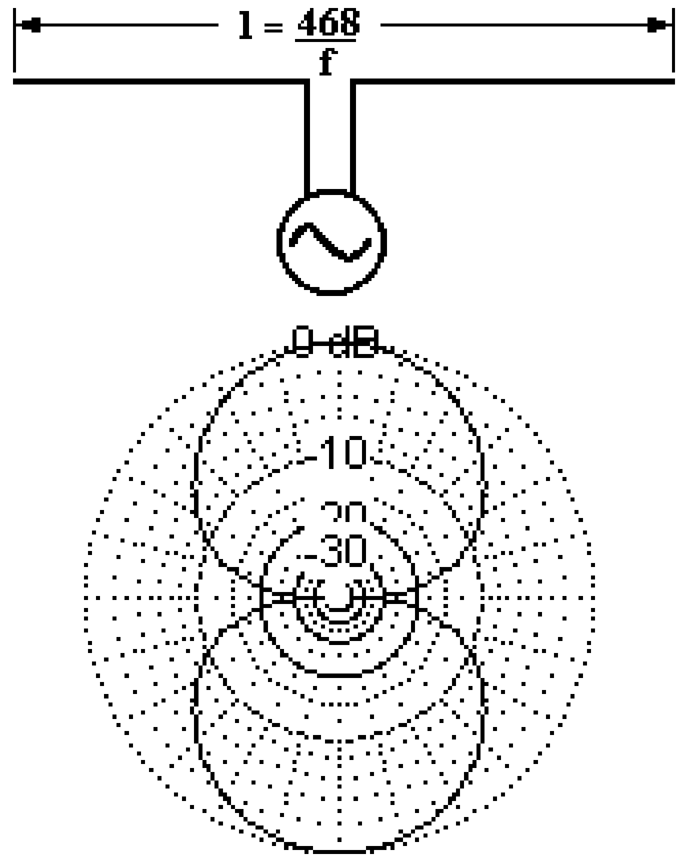
0.36 λ dipole with linear loading

BAND	LENGTH A (# 14 wire)	LENGTH B (# 14 wire)	LENGTH C (# 14 wire)	WIRE SPACING)
80 (3.6 MHz)	32 ft 3 in	16 ft 1 in	32 ft 5 in	4.5 in
75 (3.9 MHz)	30 ft 1 in	15 ft 1 in	30 ft 2 in	4.0 in

Design Height: 60 ft. Feed point impedance: 40 Ω

The Half Wave (λ/2) Dipole

- Length is approximately λ/2 (0.48λ physical for wire dipoles depending on wire diameter)
- Self impedance is 40 - 70 ohms depending on height, with no reactive component (good match to coax)
- Directivity ~ 2.1 dBi
- SWR Bandwidth is ~ 5% of design frequency



Harmonic Operation of λ/2

- A λ/2 dipole is also resonant at odd integer multiples of its resonant frequency.
- The self impedance of a λ/2 dipole at odd multiples of the resonant frequency is 100 - 150 ohms.
- The self impedance at even multiples is > 1000 ohms
- The directivity is never greater than the extended double Zepp. (two co-linear λ/2 elements)
- The pattern is very complex, with many side lobes.

Design: Half Wave Dipole

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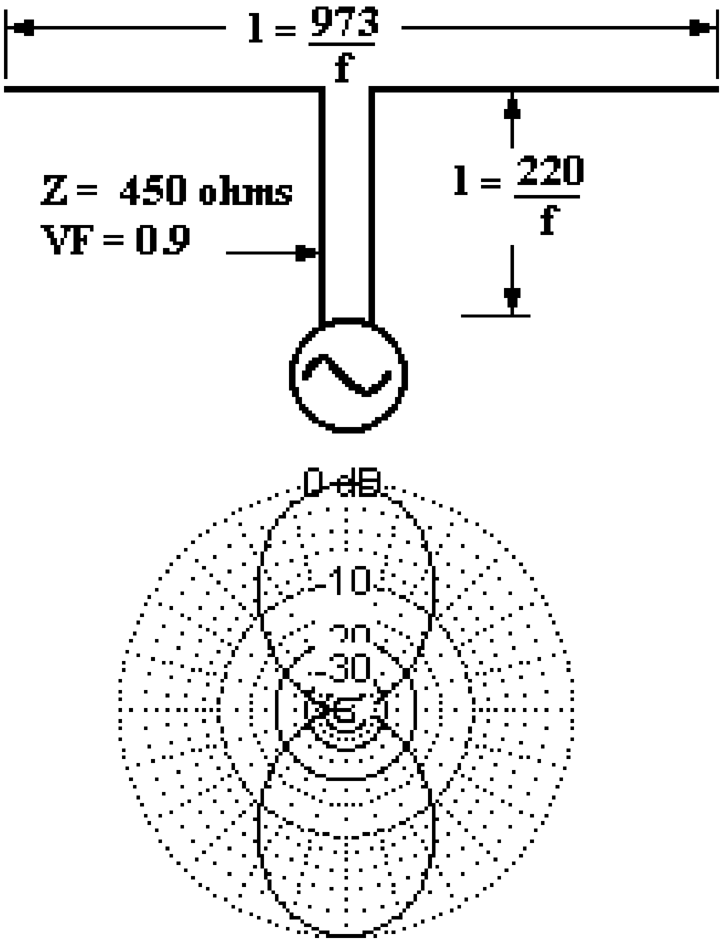
BAND	LENGTH (# 14 copper wire)
160 (1.83 MHz)	255 ft 9 in
80 (3.8 MHz)	123 ft 2 in
40 (7.1 MHz)	65 ft 11 in
30	46 ft 3 in
20	33 ft 0 in
17	25 ft 10 in
15	22 ft 1 in
12	18 ft 9 in
10 (28.4 MHz)	16 ft 6 in

Full Wave (Double Zepp)

- Length is approximately λ (0.99λ for wire dipoles)
- Self impedance is ~ 6000 ohms.
- Antenna can be matched to coax with a 450 ohm series matching section
- Directivity ~ 3.8 dBi
- SWR Bandwidth ~ 5% of design frequency

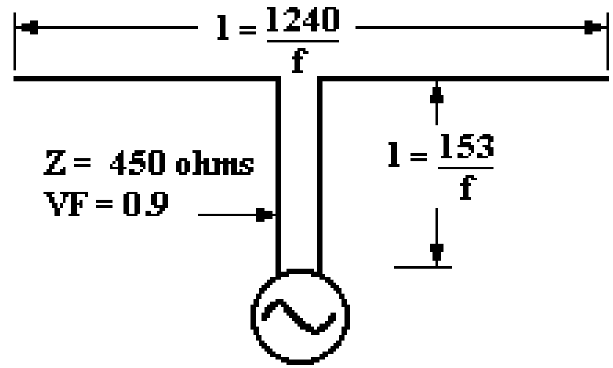


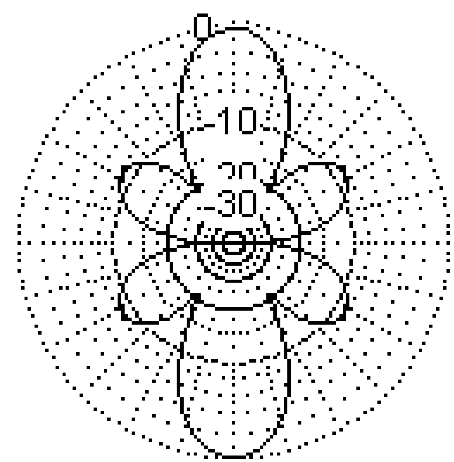
Design: Double Zepp

BAND	LENGTH OF ANTENNA (# 14 copper wire)	LENGTH OF MATCHING SECTION (450 Ω LINE VF = 0.9)
160 (1.83 MHz)	531 ft 8 in	120 ft 3 in
80 (3.8 MHz)	256 ft 1 in	57 ft 11 in
40 (7.1 MHz)	137 ft 1 in	31 ft 0 in
30	96 ft 1 in	21 ft 9 in
20	68 ft 8 in	15 ft 6 in
17	53 ft 9 in	12 ft 2 in
15	45 ft 10 in	10 ft 4 in
12	39 ft 0 in	8 ft 10 in
10 (28.4 MHz)	34 ft 3 in	7 ft 9 in

The Extended Double Zepp

- Length is approximately 1.28λ
- Self impedance is approx. 150 -j800 ohms
- Antenna can be matched to 50 ohm coax with a series matching section
- Directivity ~ 5.0 dBi. This is the maximum broadside directivity for a center-fed wire antenna





Extended Double Zepp

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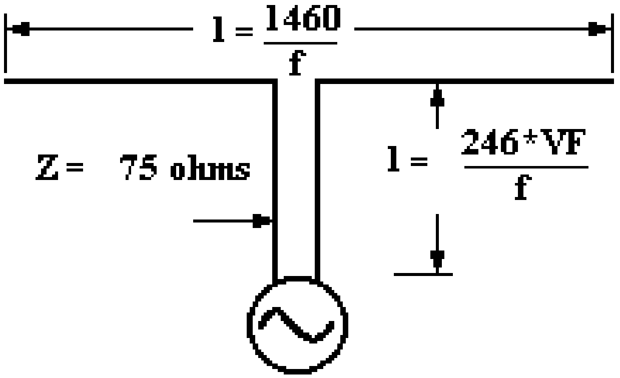
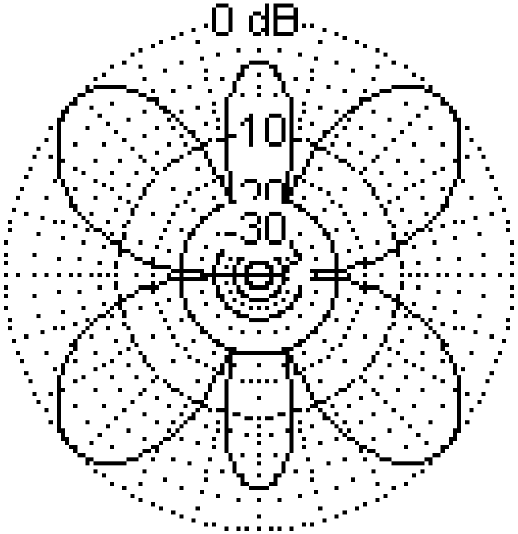
BAND	LENGTH OF ANTENNA (# 14 copper wire)	LENGTH OF MATCHING SECTION (450 Ω LINE VF = 0.9)
160 (1.83 MHz)	677 ft 7 in	83 ft 7 in
80 (3.8 MHz)	326 ft 4 in	40 ft 3 in
40 (7.1 MHz)	174 ft 8 in	21 ft 7 in
30	122 ft 6 in	15 ft 1 in
20	87 ft 6 in	10 ft 10 in
17	68 ft 6 in	8 ft 6 in
15	58 ft 5 in	7 ft 2 in
12	49 ft 8 in	6 ft 2 in
10 (28.4 MHz)	43 ft 8 in	5 ft 5 in

The 3λ/2 Dipole

- Length is approximately 1.48λ
- Self impedance ~ 110 ohms
- Antenna can be matched to 50 ohm coax with quarter wave 75 ohm matching section
- Directivity ~ 3.3 dBi.
- Directions of max radiation point to all areas of interest for HF DX when antenna wire runs E-W



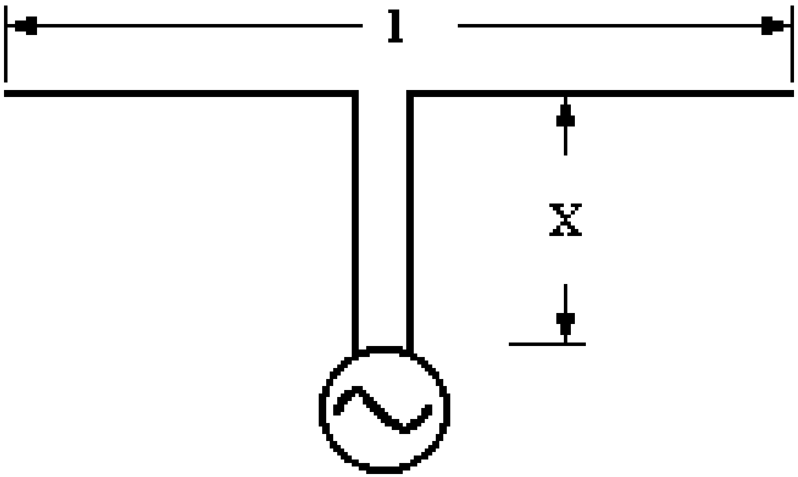


Design: 3λ/2 Dipole

BAND	LENGTH OF ANTENNA (# 14 copper wire)	LENGTH OF MATCHING SECTION (RG11 Z=75 Ω VF =0.66)
160 (1.83 MHz)	797 ft 10 in	88 ft 9 in
80 (3.8 MHz)	384 ft 3 in	42 ft 9 in
40 (7.1 MHz)	205 ft 8 in	22 ft 11 in
30	144 ft 2 in	16 ft 0 in
20	103 ft 0 in	11 ft 6 in
17	80 ft 8 in	9 ft 0 in
15	68 ft 9 in	7 ft 8 in
12	58 ft 6 in	6 ft 6 in
10 (28.4 MHz)	51 ft 5 in	5 ft 9 in

Dual Band Dipole

- It is possible to select the length of a dipole and its series matching section such that low SWR can be obtained on two bands
- The SWR bandwidth of this type of dipole is less than a regular dipole; full band coverage is not possible on most HF bands
- Note: the dipole alone is generally not resonant on either band

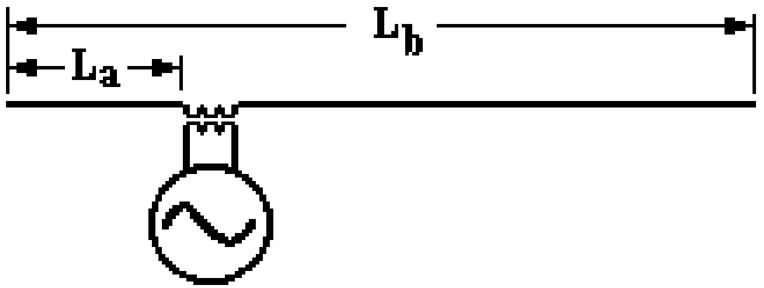


Design: Dual Band Dipole

BAND PAIR	LENGTH OF ANTENNA (L) (# 14 copper wire)	LENGTH OF MATCHING SECTION (X) (Z=450 Ω VF =0.9)
20m / 15m	51 ft 0 in	50 ft 8 in
17m / 12m	28 ft 7 in	46 ft 8 in
10m / 6m	16 ft 6 in	31 ft 5 in
75m / 40m	144 ft 10 in	89 ft 6 in
30m / 17m	54 ft 9 in	36 ft 2 in
15m / 10m	38 ft 8 in	53 ft 4 in

Off-Center Fed Dipole (OCFD)

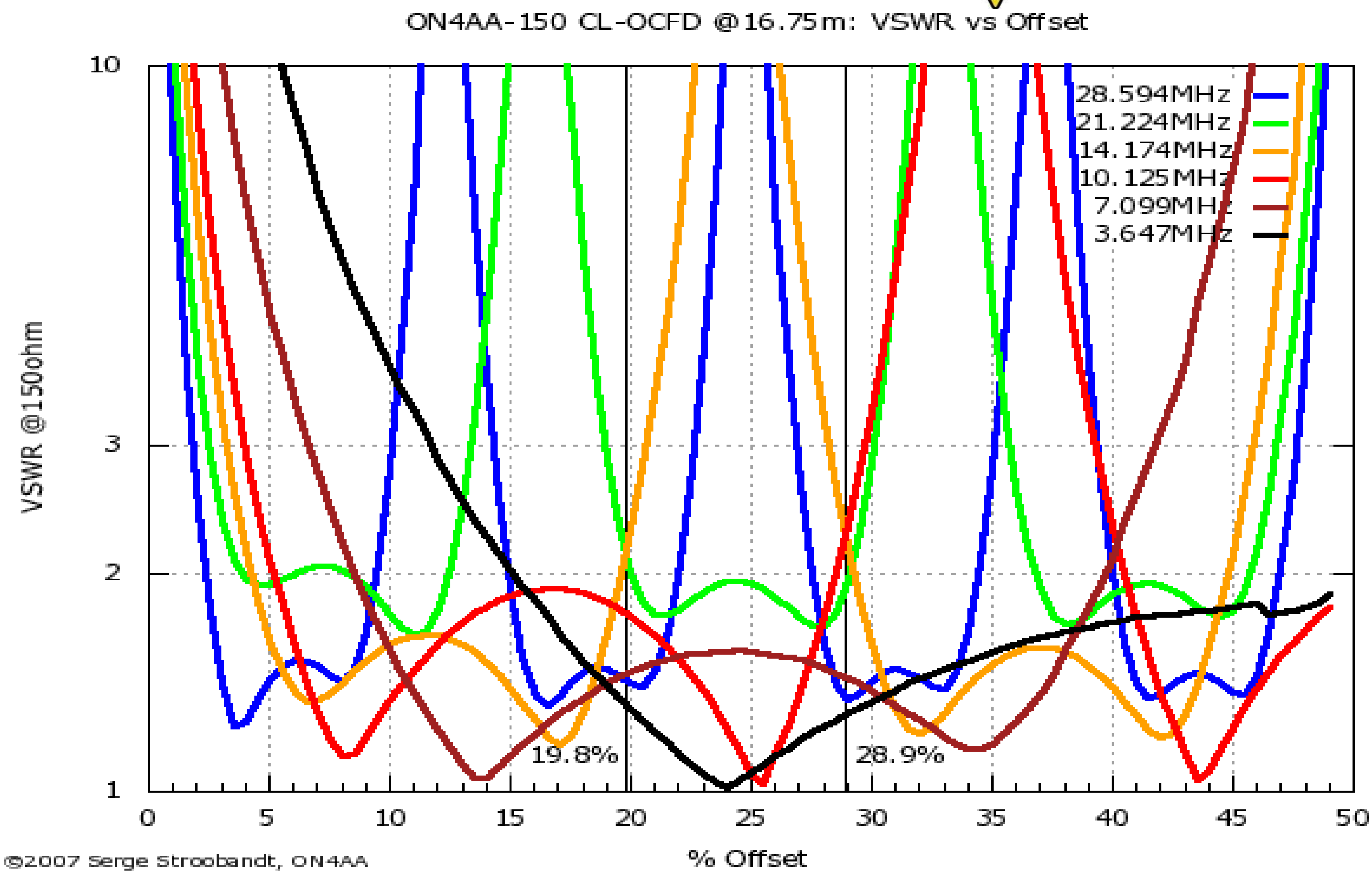
- By moving the feed point away from the center, it is possible to have a low feed point impedance at frequencies other than the odd multiples of the resonant frequency



- The feed point impedance of an OCFD is 100 – 250 ohms, necessitating use of a transformer at the feed point

- The relationship between feed position and feed impedance is very complex, but in general as the feed moves away from the center, the impedance increases and the number of harmonics with low impedance resonance increases.

OCFD Impedance vs Offset



Design: OCFD antennas

BANDS OF OPERATION	LENGTH OF SHORT LEG (L_a)	LENGTH OF LONG LEG (L_b)	NOTES
40/20/15/10	12 ft 0 in	57ft 0 in	# 14 Cu wire; use 4:1 Bal
80/40/20/15/10	23 ft 6 in	111 ft 6 in	2, #14 Cu wires spaced 8 in; use 4:1 Balun and a choke balun on the coax

See ON4AA Web Site for Detailed Design and Tuning Information

Use dipole on several bands

- It is possible to use a center fed dipole over a wide range of frequencies by:
  - feeding it with low-loss transmission line (ladder line)
  - providing impedance matching at the transceiver
- The lower frequency limit is set by the capability of the matching network. Typically a dipole can be used down to 1/2 of its resonant frequency.
- The radiation pattern becomes very complex at higher frequencies. Most of the radiation is in two conical regions centered on each wire
- There is no special length, since the antenna will not be resonant

G5RV: what is it, really?

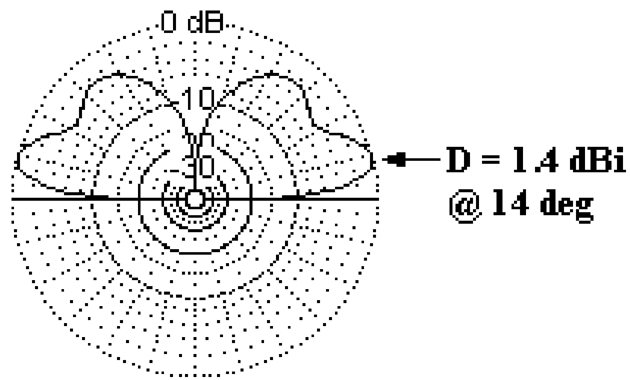
- The G5RV was originally designed as a 3 $\lambda/2$ antenna for use on 20 meters.
- It was used as a multi-band antenna because when fed with a specific length of ladder line (not coax!) it is easy to match the on any band from 80m to 10m
- A G5RV used as a multi-band antenna should be fed with a specific length of ladder line. Most commercially-made G5RV antennas are lossy because they are fed with coax.
- There is no special length for a G5RV; it only needs to be at least $\lambda/4$ long at the lowest operating frequency.
- There is nothing magic about a G5RV. It is just a non resonant dipole with open wire impedance matching

Dipole Polarization

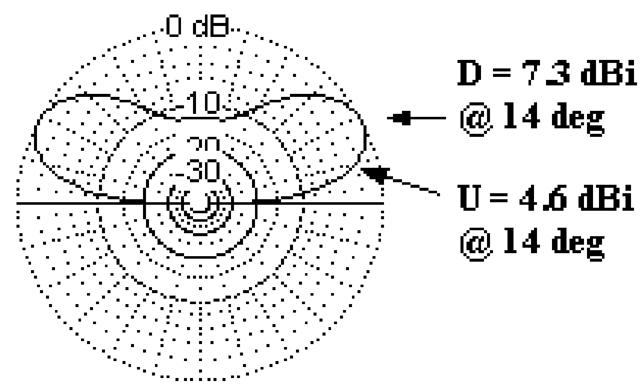
- On the HF bands dipoles are almost always horizontally polarized. It is not possible to get a low angle of radiation with a vertical dipole (electrically) close to the earth

- Reflection losses are also greater for vertically polarized RF

- The height of the support required for a vertical dipole can also be a problem



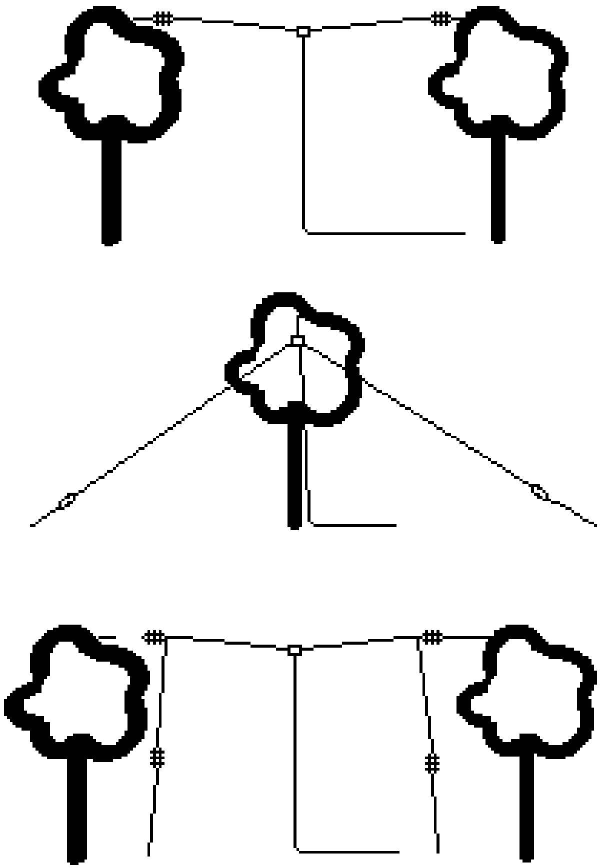
Vertical dipole ctr height = λ/2



Horizontal dipole height = λ/2

Putting up a Dipole

- A dipole may be erected between 2 supports or with one support.
- A dipole antenna using a single support is known as an "inverted-V"
- The legs of a dipole may also be bent to form an inverted U. The bend (bob tail) should be at least half way to the end of the wire



Dipole Antenna Supports

- Almost any structure can be used to support a dipole
- The antenna should be kept at least 12 inches away from a conducting support.
- If trees are used, leave some slack in the antenna so that swaying of the branches does not snap the wire
- Pulleys (Blocks) with rubber tarp straps can be used to allow the antenna to move without breaking.
- The support should be tall enough that the dipole is at least 1/2 wavelength above the surrounding terrain ($\lambda/2$ =492/f MHz)

Other useful information

- Do not run a dipole above / near power lines!!!!
- When the feed line leaves the dipole, it should run perpendicular to the dipole for at least 1/4 wavelength
- Avoid running the dipole parallel to long conducting objects such as aluminum gutters. The antenna can couple to the other metal and be detuned
- When erecting a dipole as an inverted-V, remember that the voltage at the ends of the antenna may be above 1000 V. The ends of the antenna should not be so close to ground that a person could touch them
- When erecting an inverted-V, the angle between the wires should be greater than 90 degrees

Antenna Comparison

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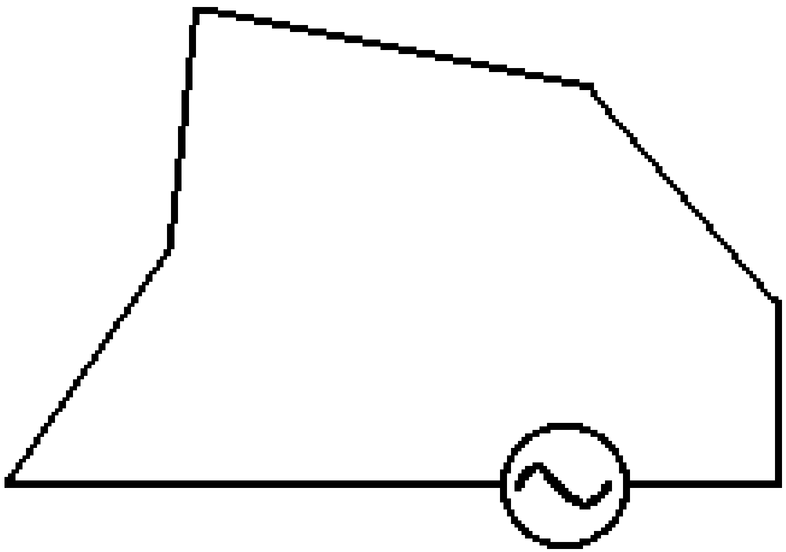
ANTENNA	GAIN (dBi)	Pros	Cons
Short Dipole	1.8	Can be made very short	Heavy, can have high losses, difficult to match
λ/2 dipole	2.1	Direct coax feed	Low gain
Double Zepp	3.8	Higher gain	Long, high voltage at feed point
Ext. Dbl Zepp	5.0	Highest gain	Very long
3λ/2 dipole	3.3	Radiates well in 6 directions	Very long, less gain than Ext. Dbl. Zepp
Dual dipole	2 - 4	Good match on two bands without LC network	Lower SWR bandwidth, may have low gain
OCD	2 - 4	Good match on several bands, good bandwidth	Transformer required. Complex to assemble

Loop Antennas

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.

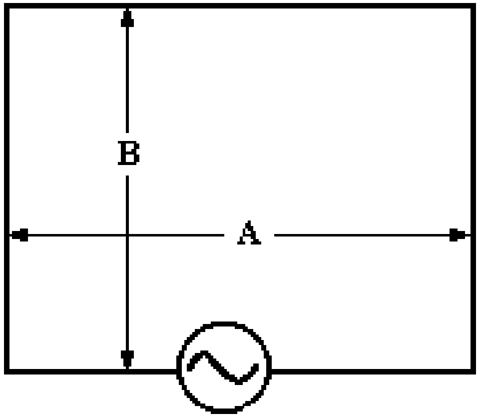


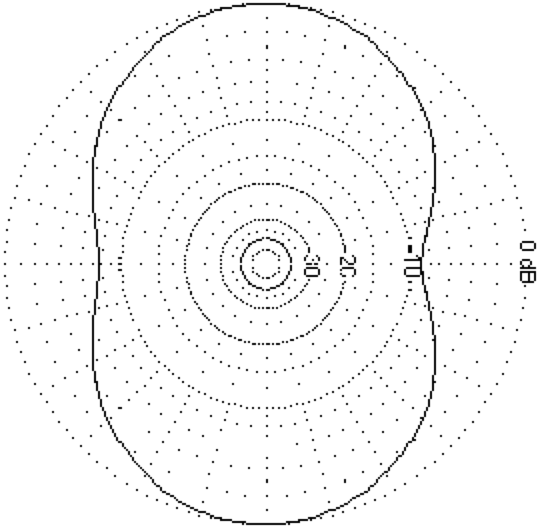
Loop Characteristics

- Electrical length - the overall length of the loop 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 virtual resistance that represents power flowing out of the antenna into free space impedance
- Radiation Pattern - the intensity of the radiated RF as a function of direction.

The Rectangular Loop

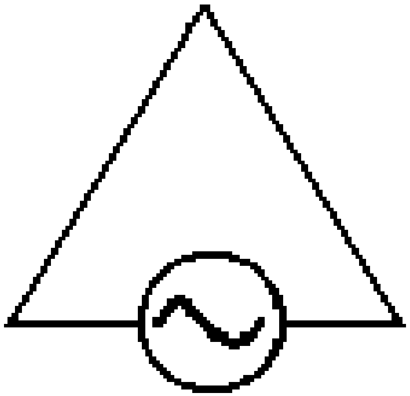
- The total length is approximately 1.02 λ.
- The self impedance is 100 - 130 Ω depending on height.
- The Aspect Ratio (A/B) should be between 0.5 and 2 in order to have Z_s ~ 120 Ω.
- SWR bandwidth is ~ 4.5% of design frequency.
- Directivity is ~2.7 dBi. Note that the radiation pattern has no nulls.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

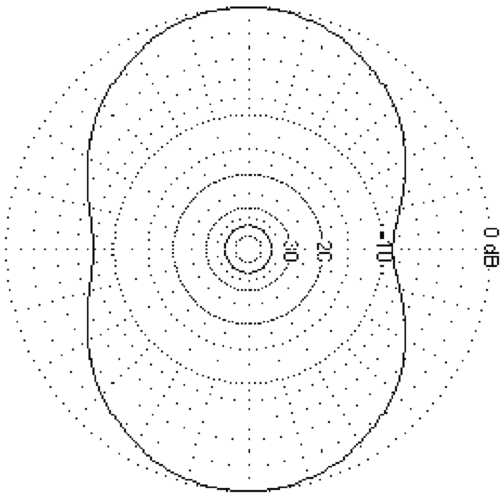




The Delta Loop

- 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.



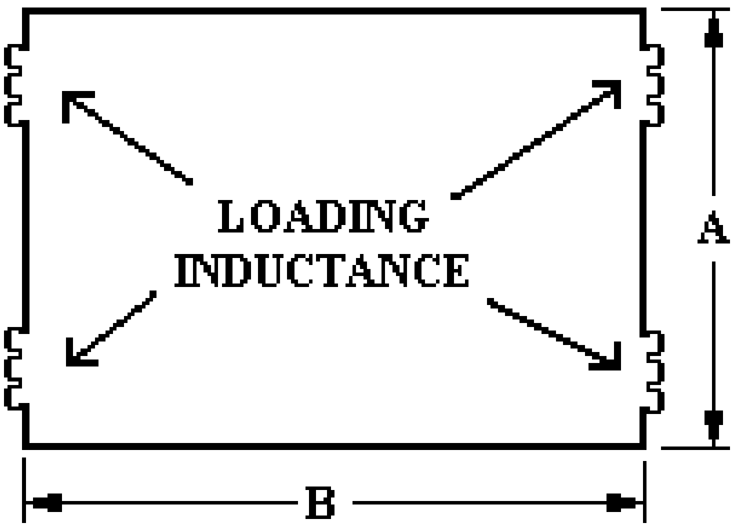


Design: Rectangular and Delta Loops

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: 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

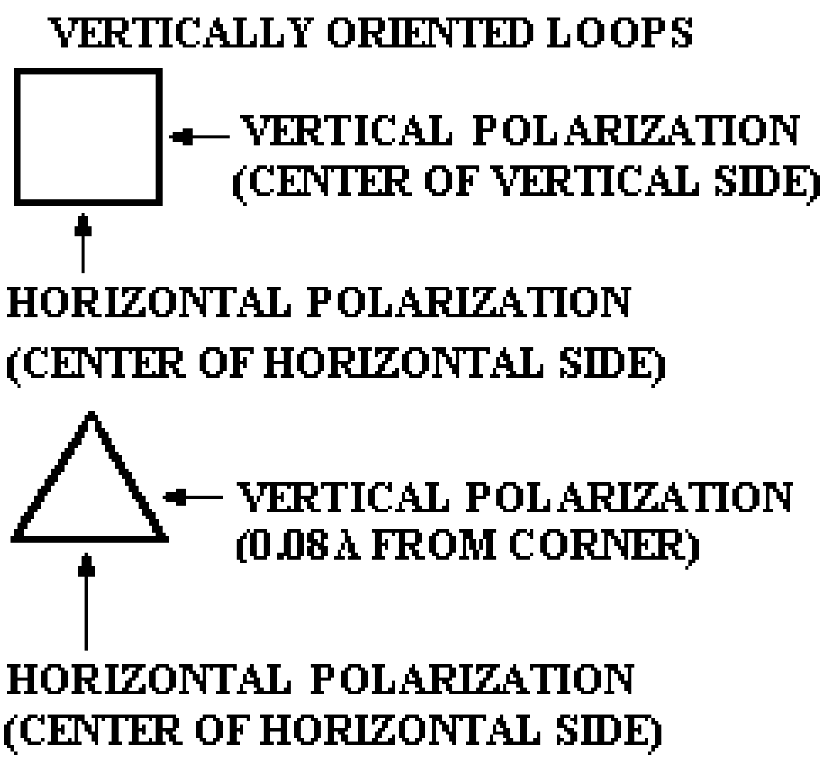
The loop is vertically oriented, with the lower wire approximately 10 feet above ground

Harmonic Operation of Loops

- A loop antenna is also resonant at integral multiples of its resonant frequency.
- The self impedance of a λ/2 loop 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.

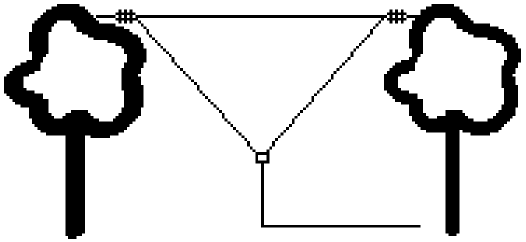
Polarization of Loops

- 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

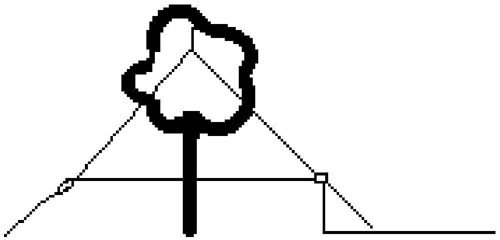


Putting up a loop

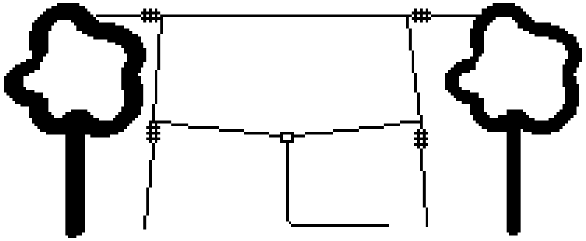
- Vertically oriented loops may be erected with one or between 2 supports



- A Horizontally oriented loop will require at least 3 supports



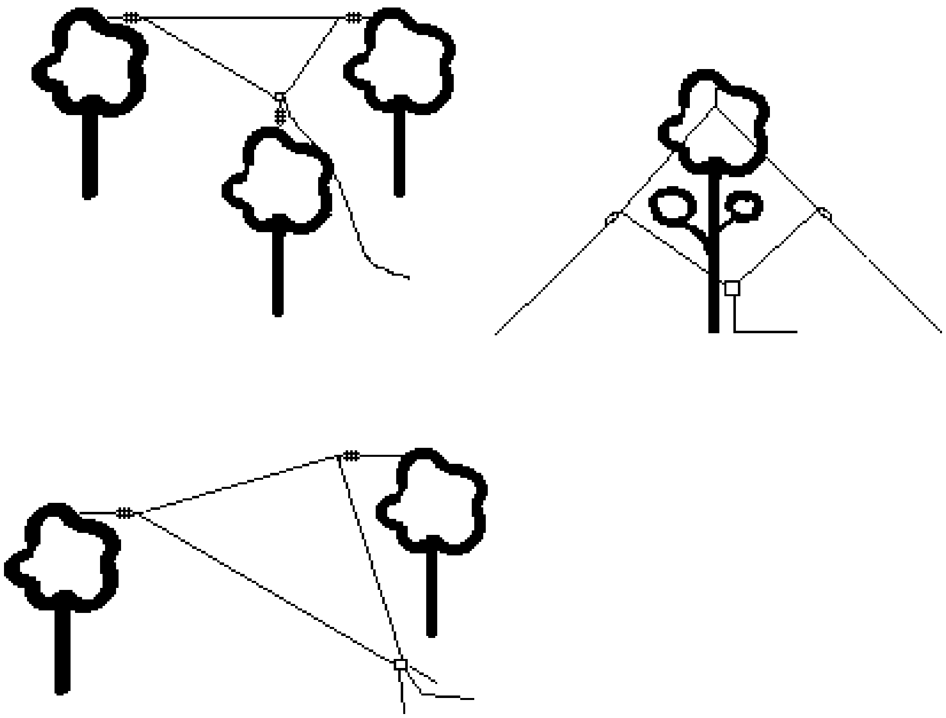
- When more than one support is used, they do not have to be exactly the same height



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



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Vertical Antennas

Characteristics of Vertical Antennas

- **Electrical length - the overall length of the antenna in <u>wavelengths</u> at the frequency of interest.**
- **Takeoff Angle - the elevation angle for which the radiation is maximum.**
- **Self Impedance - the impedance at the antenna's feed point (radiation resistance + ground losses).**
- **Ground Loss Resistance - a that portion of the feed-point resistance that represents power lost in the ground system (can be greater than the radiation resistance)**
- **Reflection Losses - reduction in far field strength due to reflection of signals from the ground. (ground is a poor reflector for vertically polarized RF).**

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 such as elevated, resonant radials.

- Counterpoises are most practical in the VHF range – can also be used at HF, but ground radial systems are generally used.

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 ~ $\lambda/4$
- Elevated counterpoise wires are usually ~ $\lambda/4$ long

Radial/Counterpoise Layout

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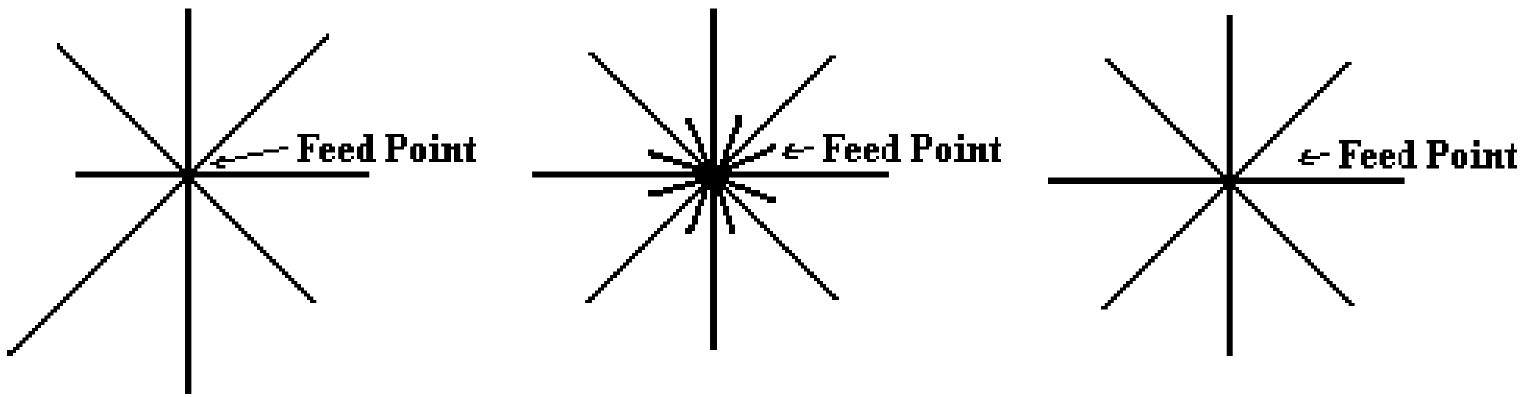
- Note: The radials used in a counterpoise are not grounded !!



Ground Radial System with random length radials on ground

Ground Radial System with extra short radials in high current region

Elevated Counterpoise using λ/4 radials

Elevated Resonant Radials

- Elevated, resonant radial systems can be highly efficient when correctly implemented
- Two to six elevated, resonant radials can be as efficient as 60 buried radials
- The radials should be < $\lambda/4$ and extend from the feed point like spokes of a wheel six or more feet above ground level
- The radials are tied together and gang resonated back to the feed-point with a single inductor
- The feed-point and coax shield need to be isolated from ground with choke balun or inductor
- Elevated radials can recover 90% of vertical current

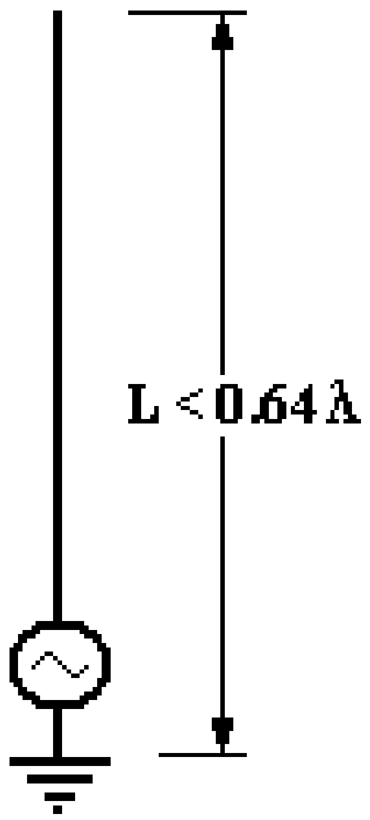
Ground Radials for $\lambda/4$ Vertical Monopole

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 used
- The radial system may be elevated above the earth (this is known as a counterpoise system)

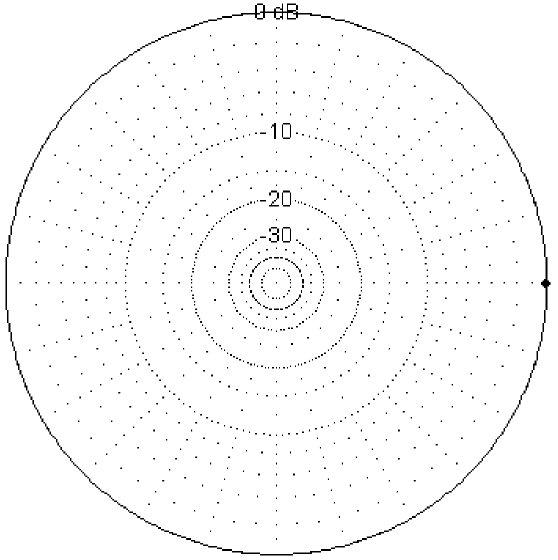
Vertical Monopoles

- 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

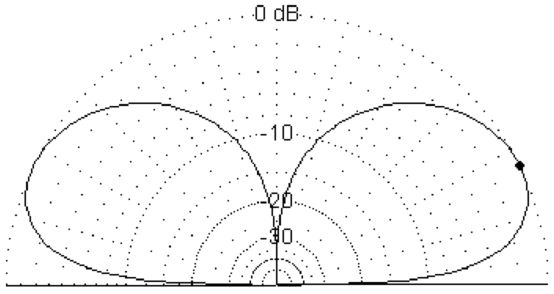


$\lambda/4$ Vertical Monopole

- **Length ~ 0.25λ**
- **Self impedance: Z_S ~ 36 - 70 Ω depending on ground loss resistance**
- **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 number of radials**
- **Take off angle ~ 25 deg**



Azimuth Plot



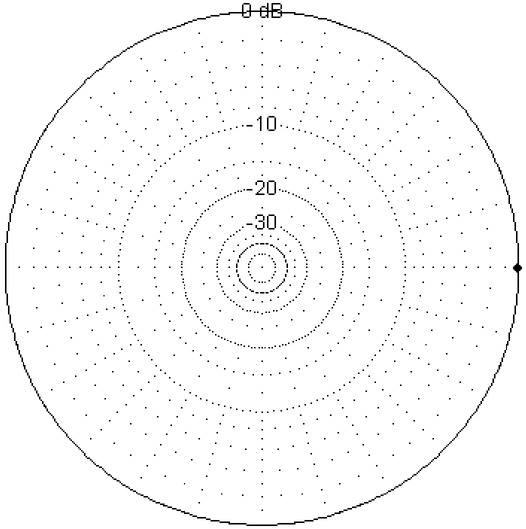
Elevation Plot

λ/4 Vertical Monopole

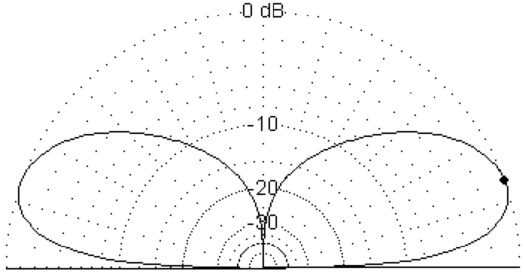
BAND	LENGTH OF MONOPOLE (#14 wire)
160 (1.83 MHz)	127 ft 10 in
80 (3.60 MHz)	65 ft 0 in
75 (3.90 MHz)	60 ft 0 in
40 (7.10 MHz)	33 ft 0 in
30	23 ft 1 in
20	16 ft 6 in
17	12 ft 11 in
15	11 ft 0 in
12	9 ft 5 in
10 (28.4 MHz)	8 ft 3 in

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 or Zepp λ/4 line
- Take off angle ~ 15 deg
- Ground currents at base of antenna are small; radials are less critical for λ/2 vertical



Azimuth Plot



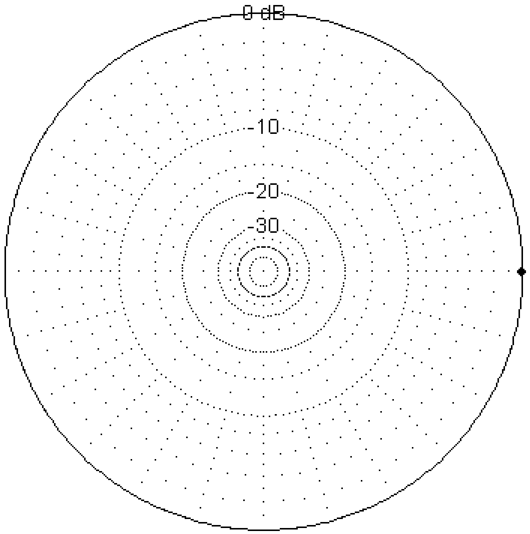
Elevation Plot

Design: λ/2 Vertical

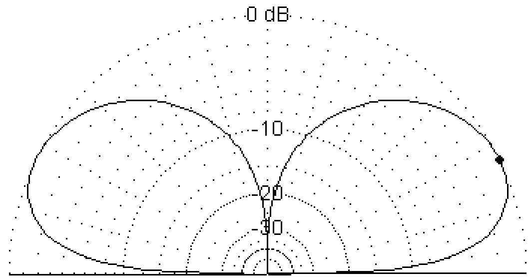
BAND	LENGTH OF MONOPOLE (#14 wire)
160 (1.83 MHz)	255 ft 8 in
80 (3.60 MHz)	130 ft 0 in
75 (3.90 MHz)	120 ft 0 in
40 (7.10 MHz)	66 ft 0 in
30	46 ft 2 in
20	33 ft 0 in
17	25 ft 10 in
15	22 ft 0 in
12	19 ft 0 in
10 (28.4 MHz)	16 ft 6 in

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

(λ/8) Vertical Monopoles

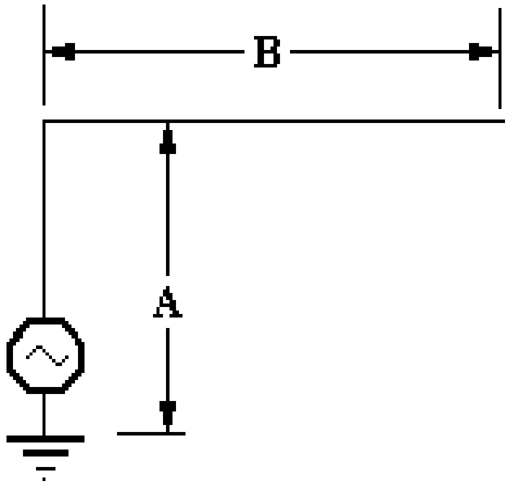
BAND	LENGTH OF MONOPOLE (#14 wire)
160 (1.83 MHz)	67 ft 2 in
80 (3.60 MHz)	34 ft 2 in
75 (3.90 MHz)	31 ft 6 in
40 (7.10 MHz)	17 ft 4 in

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
- Provides both vertical and horizontal polarization
- Series capacitor can be used to match antenna to coax
- Requires good ground system



Design: 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

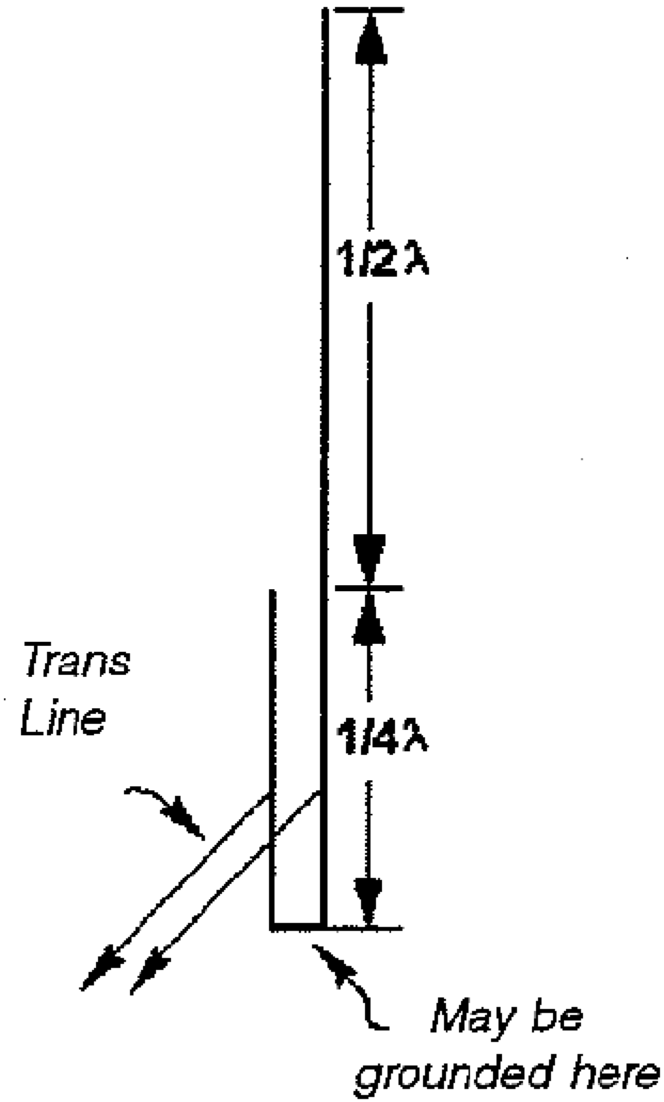
Use of a Vertical Monopole on several bands

- 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
- Multiple elevated, resonant, radial lengths can be used for each frequency band
- Multiple vertical monopoles can be feed in parallel (fanned) to make a multiband antenna

Vertical Antenna Supports

- Almost any structure can be used to support a vertical
- 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

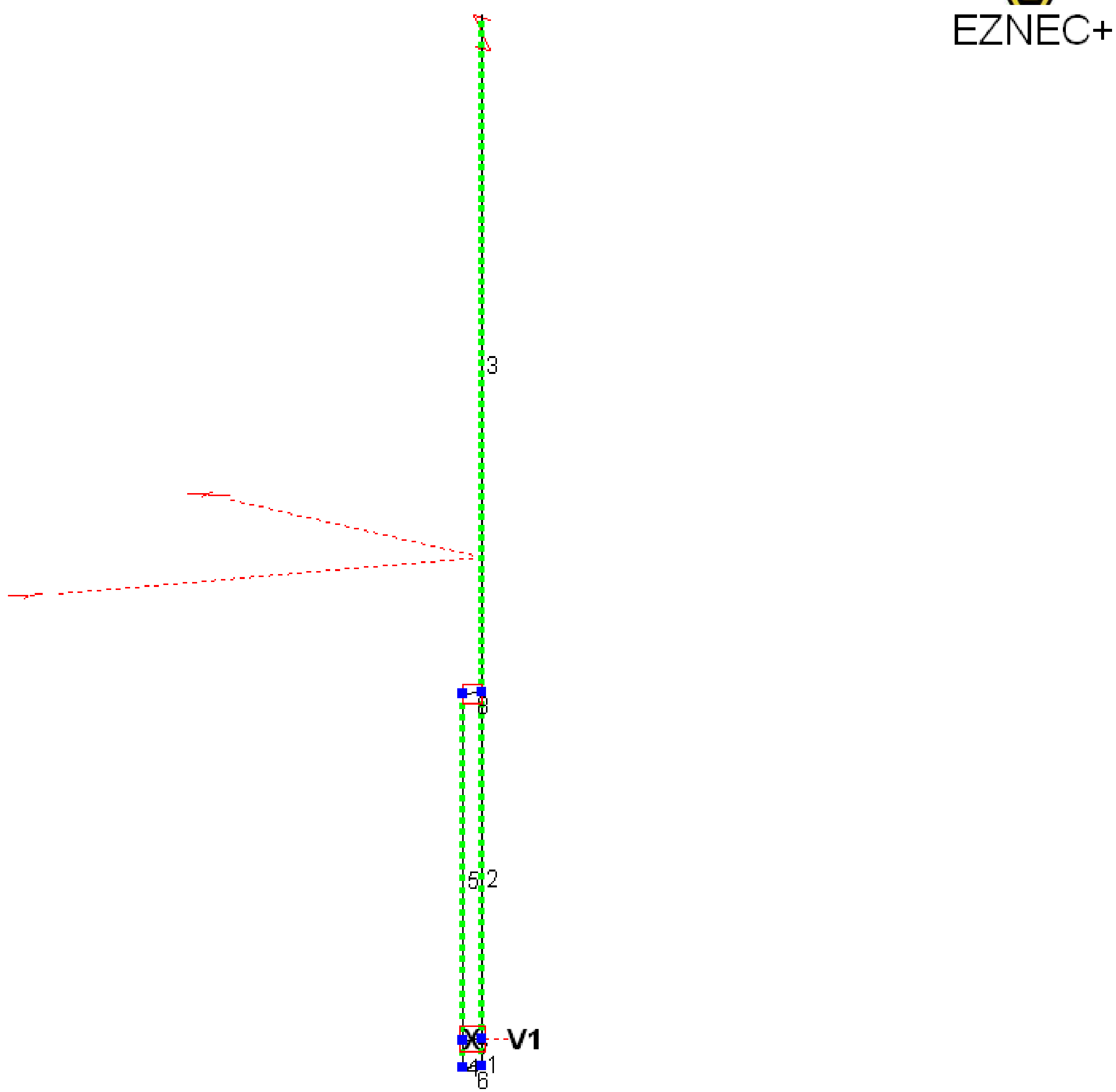
Vertical J-Pole on HF Bands



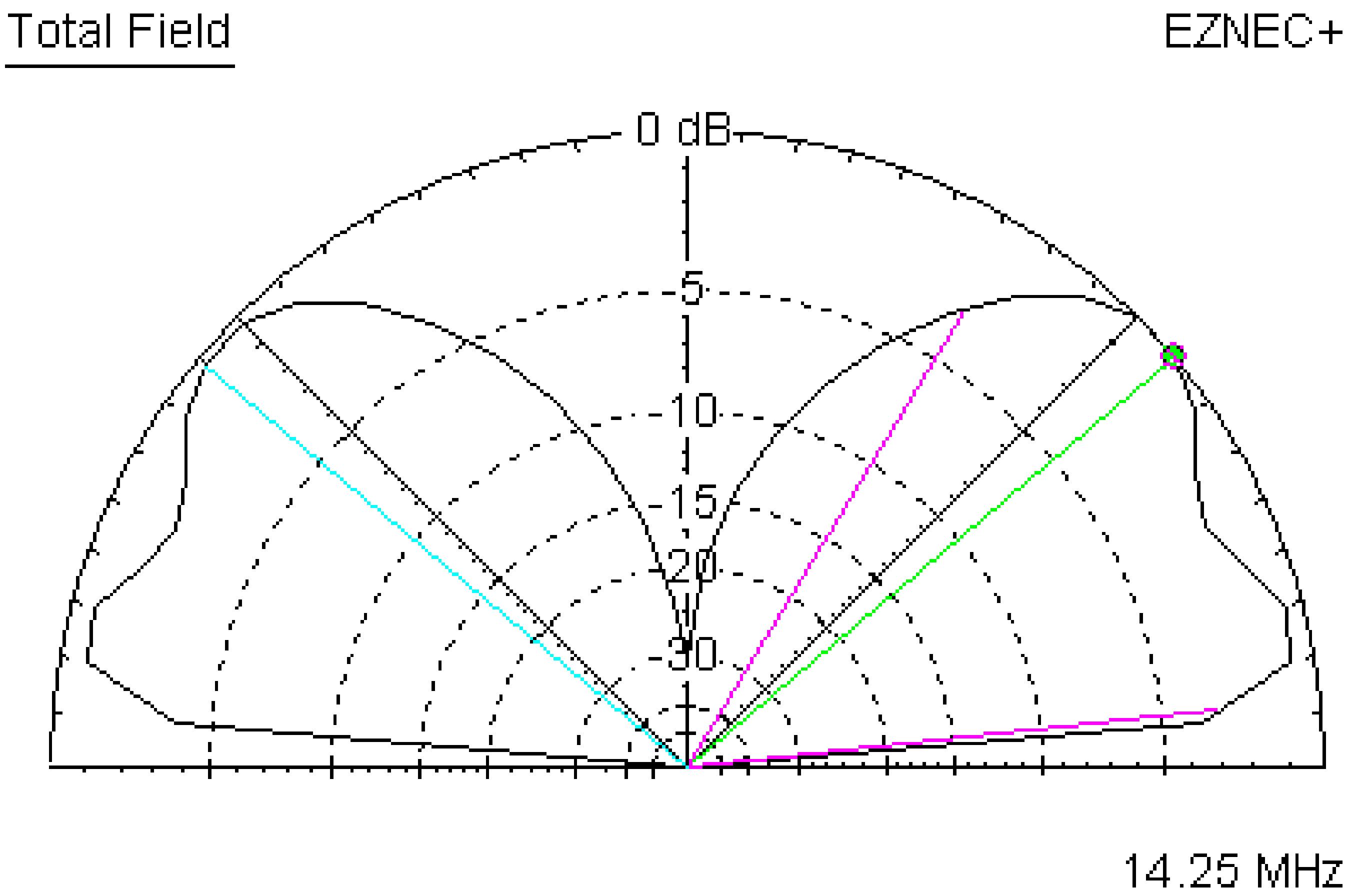
Vertical J-Pole on HF Bands

- J-Pole is $\lambda/2$ vertical radiator, end-fed with shorted stub
- Normally used for VHF and UHF applications, but works equally well for HF
- Low angle of vertical radiation without need for radials
- Gain over $\lambda/4$ vertical
- All elements at DC ground for static drain
- Balanced ladder line shorted stub with balun (rf choke) at feed
- 2000 to 4000-ohms at end of $\lambda/2$ radiator and zero at bottom of the $\lambda/4$ shorted stub
- 50-ohm feed point is near shorted end of stub
- Tuning - adjusting three things
  - $\lambda/2$ radiator length
  - $\lambda/4$ stub length
  - position of feed point on the stub

Vertical J-Pole EZNEC Model



J-Pole Elevation Pattern



J-Pole Construction

J-Pole HF Dimensions

ARRL Amateur Radio

W8GNM J-Pole Antenna Design								
Date: 3/14/2010								
By: Geoff Mendenhall								
Center	1.5:1.0 VSWR	Top Radiator	Top Radiator	Top Radiator	Stub (Zo),	Stub (Vp),	Stub	Stub Short to
Frequency (MHz)	Bandwidth (kHz)	Wire Size	Wire Jacket [Eo, Th (in)]	Wire Length (FT)	(Wire Size)	Wire Spacing (mm)	Overall Length (FT)	Feedpoint (in)
14.240	180	#14, 0.075"	4.5, 0.03"	32.58', 32' 7"	420, #14 (19/27) Stranded	Vp = 0.933, 70mm	16.12', 16' 1.4"	11.00"
						Open Wire Stub		
14.240	180	#14, 0.075"	4.5, 0.03"	33.125', 33' 1.5"	370, #14 (19/27) Stranded	Vp = 0.91, 21mm	15.75', 15' 9"	10.00"
18.130		#14, 0.075"	4.5, 0.03"	25.790', 25' 9.5"	370, #14 (19/27) Stranded	Vp = 0.91, 21mm	12.37', 12' 4.4"	7.85"
21.300		#14, 0.075"	4.5, 0.03"	22.15'	370, #14 (19/27) Stranded	Vp = 0.91, 21mm	10.53', 10' 6.4"	6.69"
24.950		#14, 0.075"	4.5, 0.03"	18.91'	370, #14 (19/27) Stranded	Vp = 0.91, 21mm	8.99', 8' 11.5"	5.71"
28.800		#14, 0.075"	4.5, 0.03"	16.38'	370, #14 (19/27) Stranded	Vp = 0.91, 21mm	7.79', 7' 9.5"	4.94"
14.275		#14, 0.075"	4.5, 0.03"	30.9', 30' 11"	430, #16 solid	Vp = 0.91, 21mm	15.72'	11.00"
18.130		#14, 0.075"	4.5, 0.03"	24.4'	430, #16 solid	Vp = 0.91, 21mm	12.4'	8.70"
21.300		#14, 0.075"	4.5, 0.03"	20.8'	430, #16 solid	Vp = 0.91, 21mm	10.54'	7.37"
24.950		#14, 0.075"	4.5, 0.03"	17.7'	430, #16 solid	Vp = 0.91, 21mm	8.99'	6.29"
28.800		#14, 0.075"	4.5, 0.03"	15.4'	430, #16 solid	Vp = 0.91, 21mm	7.79'	5.45"

Wire Antenna Construction Materials and Techniques

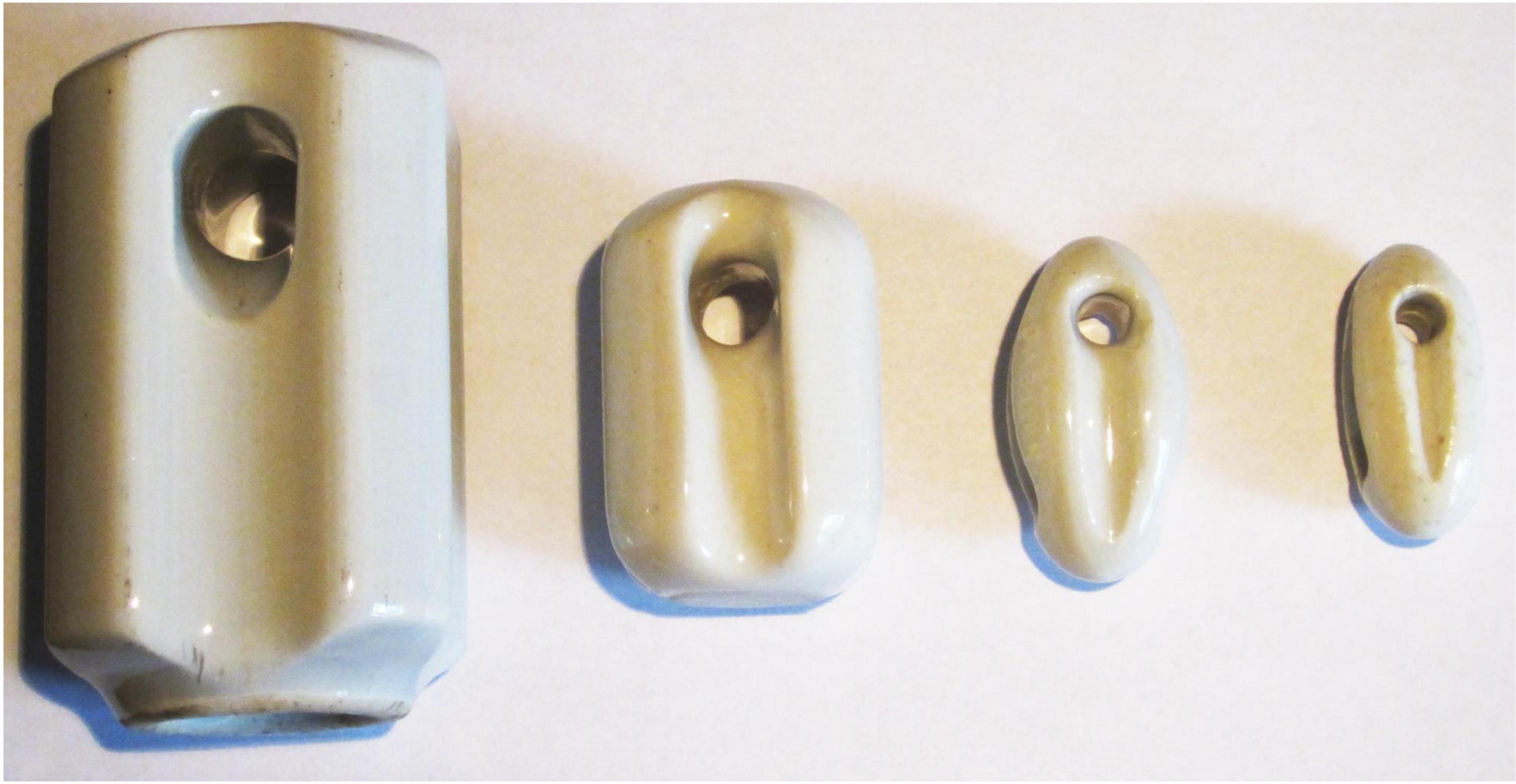
Antenna Construction Materials

- **Wire**
  - **#14 Copperweld**
    - **very strong**
    - **kinks very easily; difficult to work with**
    - **does not stretch**
    - **subject to corrosion**
  - **#14 THHN stranded copper with insulation**
    - **moderately strong**
    - **easy to work with, does not kink**
    - **can stretch under high tension (a problem with long antennas)**
    - **does not corrode**
  - **#14 Davis Flex weave**
    - **Available without and with jacket…black and green**
    - **Does not kink**
    - **Many strands with greater surface area for better RF conductivity**
    - **Resistant to stretch**

- Insulators
  - Ceramic
    - strong
    - resist very high voltages
    - not affected by sunlight
    - Expensive
  - Plastic…various types
    - weaker than ceramic insulators
    - moderately resist high voltages
    - some materials will melt or burn when subjected to corona
    - can be degraded by sunlight
    - relatively inexpensive

"Johnny Ball" / Egg Insulators

Interlocking provides structural integrity in case of insulator failure



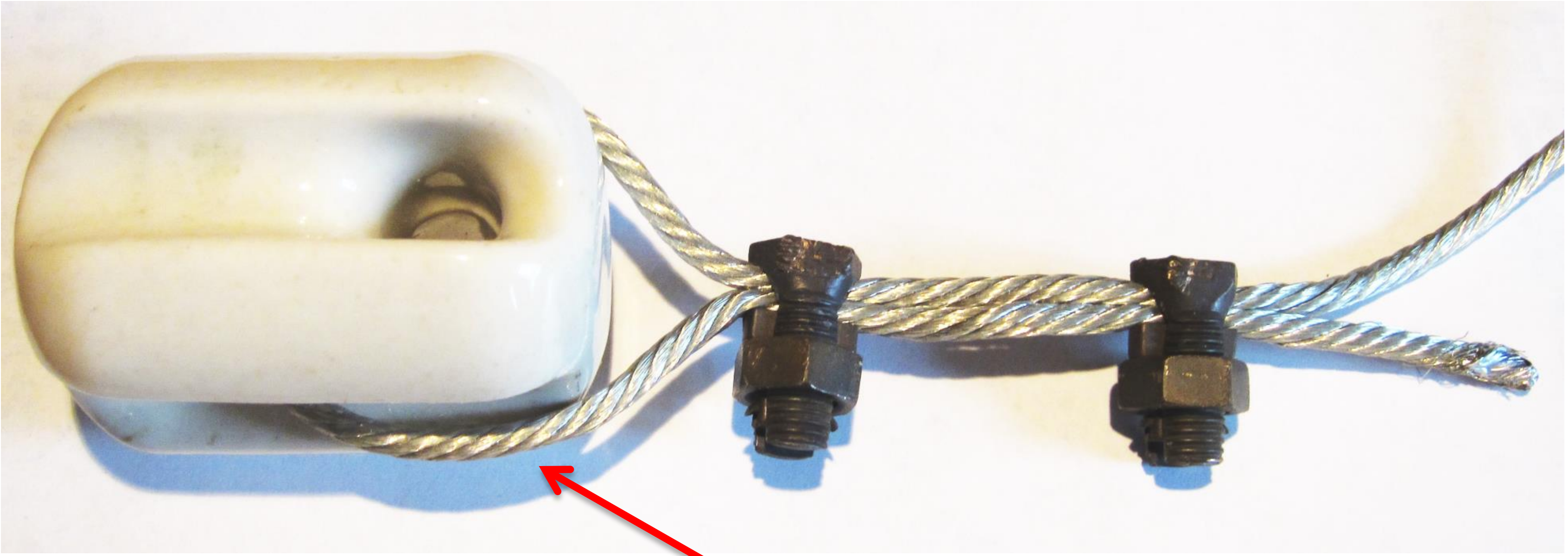
6 Inch Long Bar Insulator

Provides higher voltage capability

Non interlocking, so not failsafe like “Johnny Ball” insulators

End Length Adjustment

Split bolts allow easy antenna length adjustment at end insulators

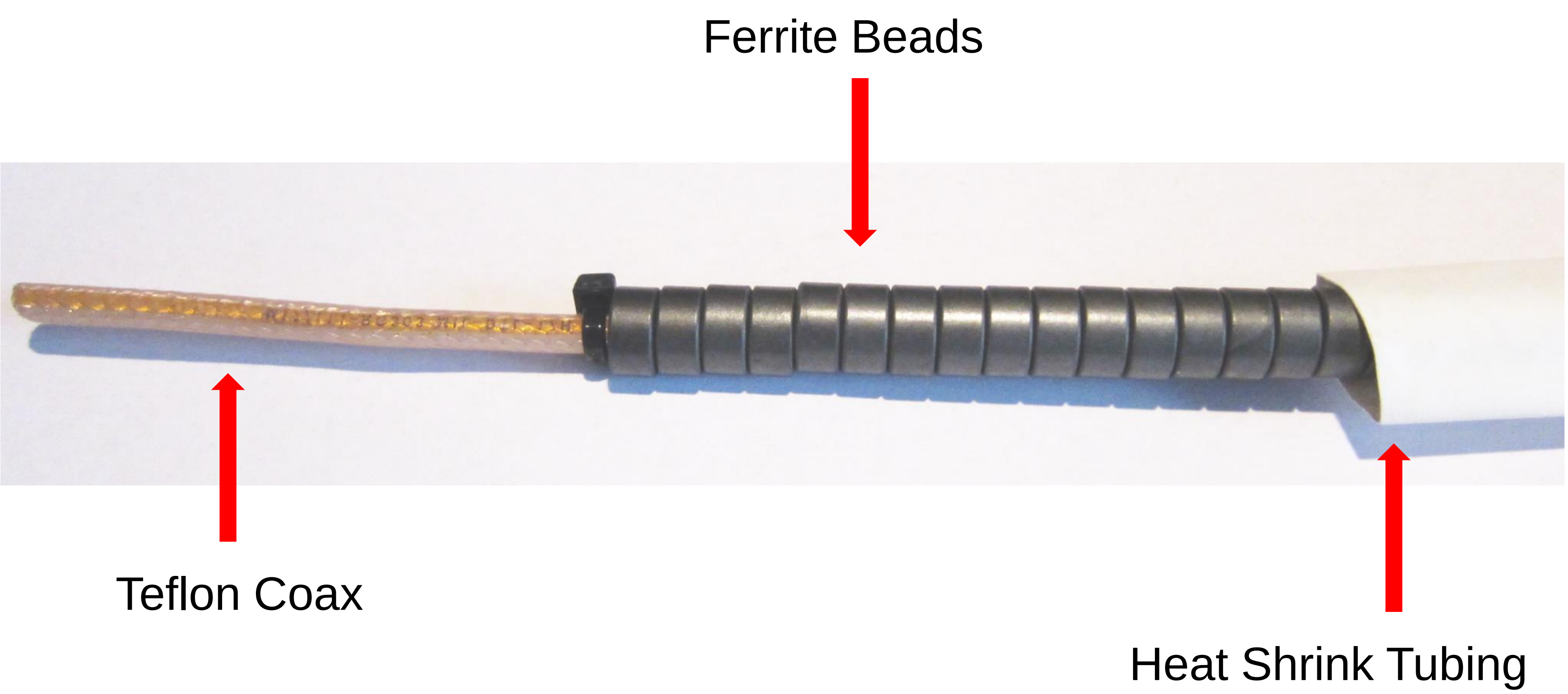


End loop reduces corona

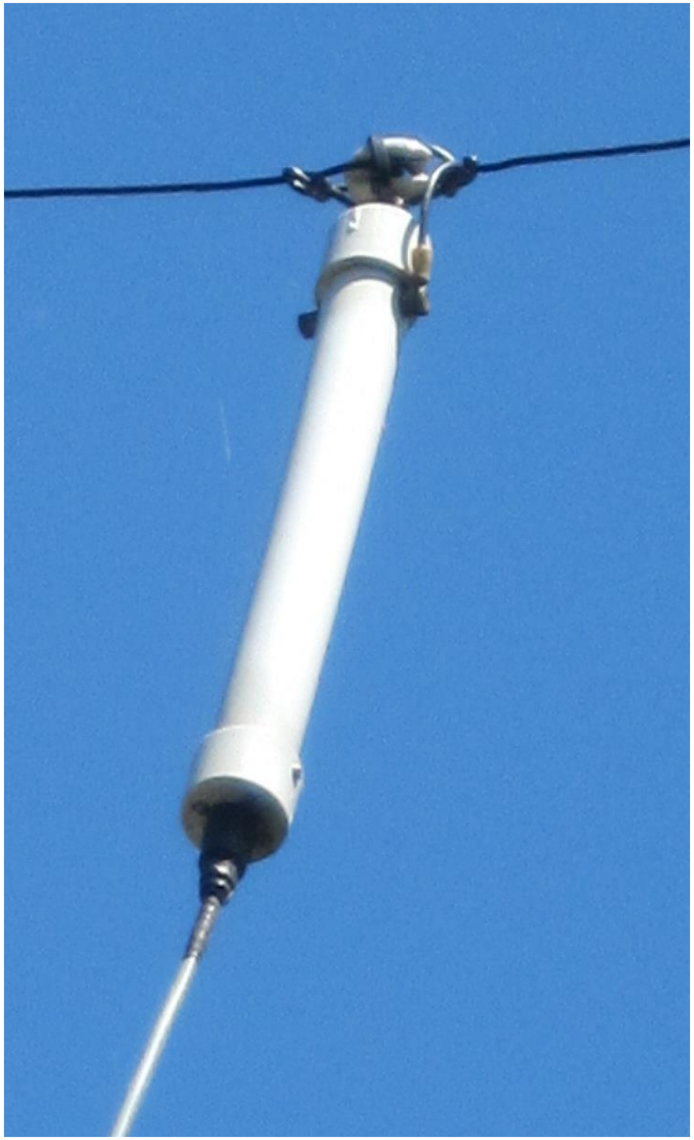
- **Baluns**
  - Choke balun (several turns of coax wound into coil ~ 6 in in dia) is usually sufficient unless impedance transformation is required
  - Choke balun can be ferrite beads over shield of coax
  - Powdered-iron core baluns should be used within their ratings to avoid core saturation.

- **Support ropes**
  - should be at least 3/16 inch diameter and UV stabilized
  - UV stabilized Dacron or Nylon work well
  - Kevlar jacket line is ideal
  - Polyolefin ropes quickly degrade in sunlight

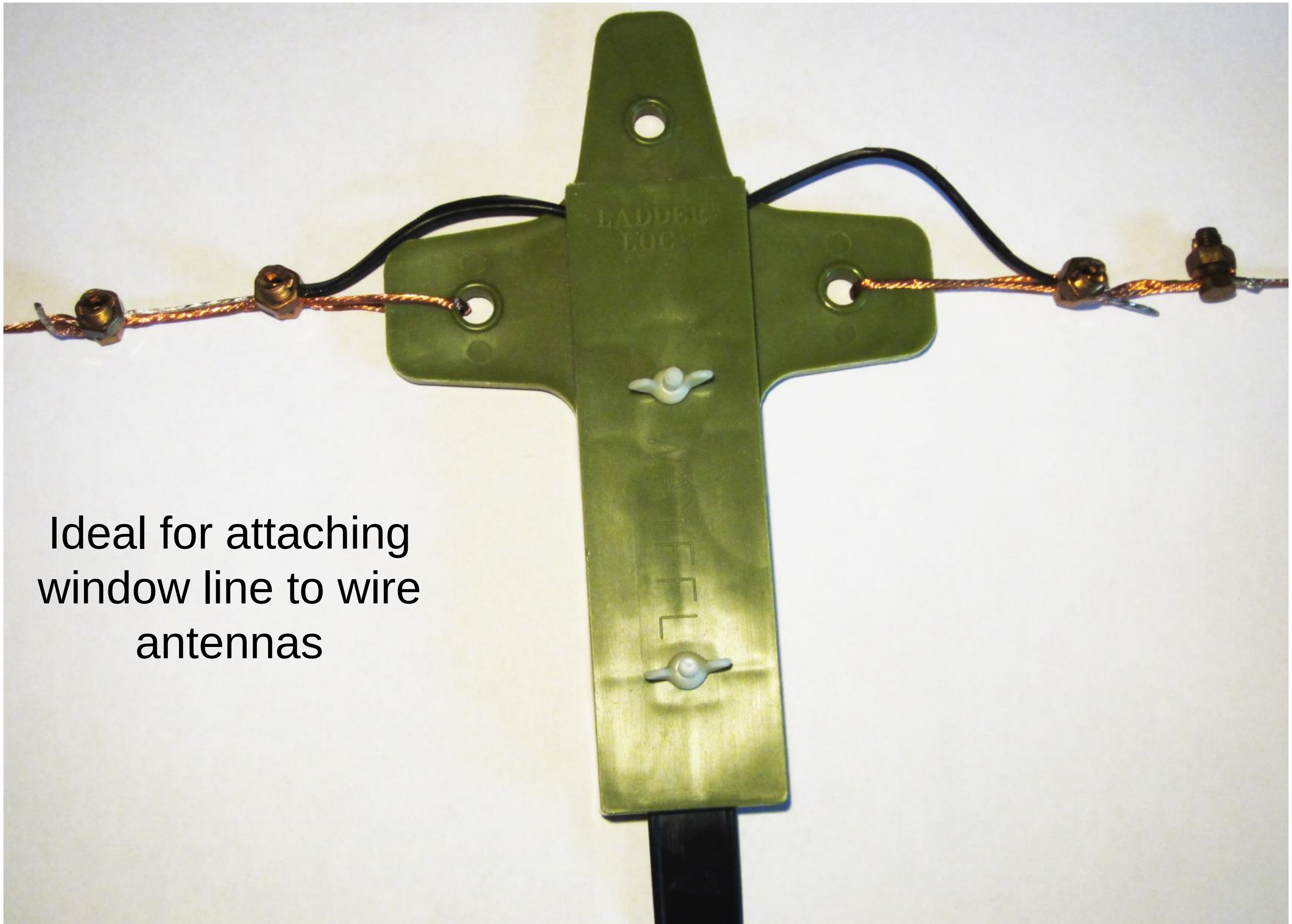
Ferrite Bead Balun



Ferrite Bead Balun in PVC Pipe

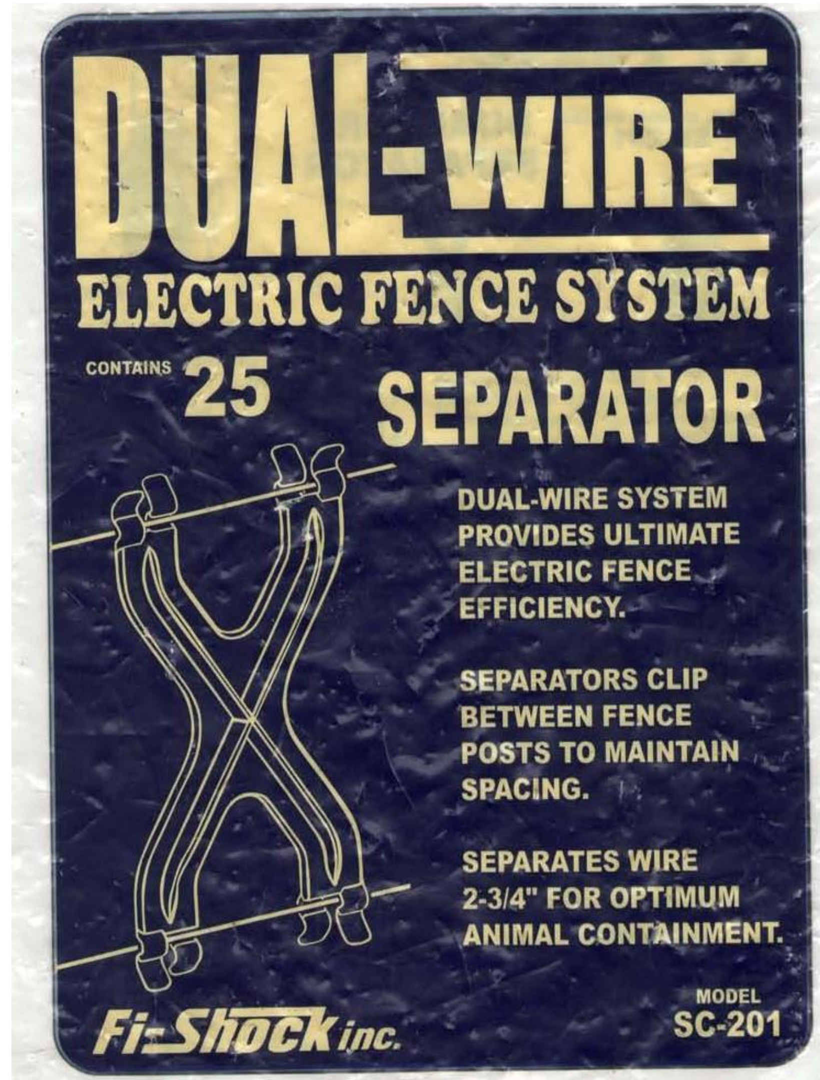


Ladder Loc for Window Line



Ideal for attaching window line to wire antennas

Electric Fence Insulator
Open Wire Spacer



Ladder Snap Open Wire Spacer

Ladder Snap™ The hottest thing going for Hi Performance Amateur Radio Feedline.
Now make your own 600-Ohm ladder line in a Snap! Ladder Snap™ now allows you to effortlessly build your own balanced feed line using #14 THHN wire (Solid or Stranded) available at home improvement stores everywhere. Easily and quickly snap together whatever length feed line you need for your antenna project.
Ladder Snap™ high performance, low loss and cost effective, Made right here in the USA from Engineering Grade UV Stabilized Delrin Material. Good for up to 5000 Watts of RF Power. Recommended spacing 18 inches.

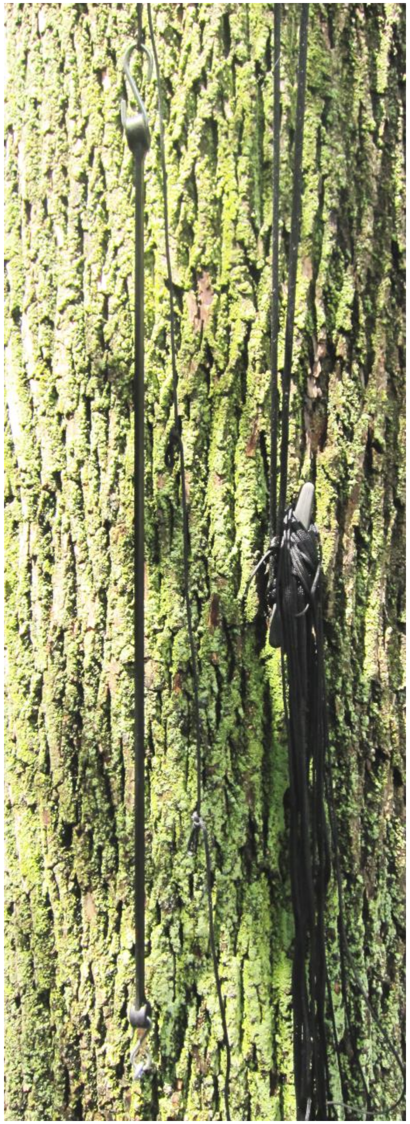
Available exclusively at www.73CNC.com

Made In USA

Insulated Pulley for "Bob Tail"

Cleat for securing antenna halyard

Bungee Cord for Tensioning



Questions and Answers