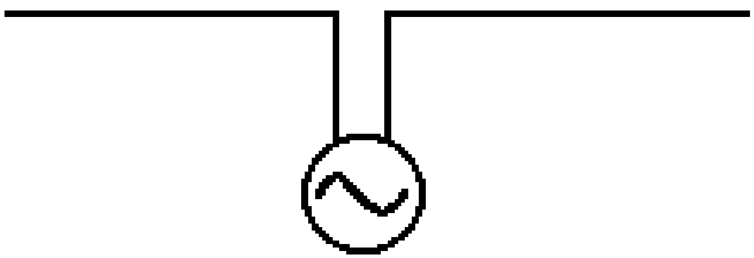
Basic Wire Antennas

Part I: Dipoles

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.

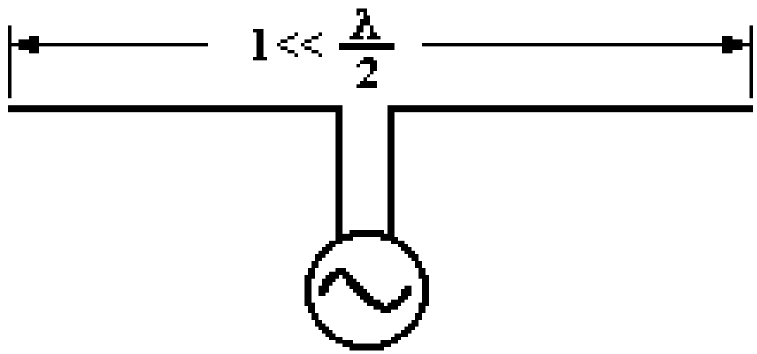


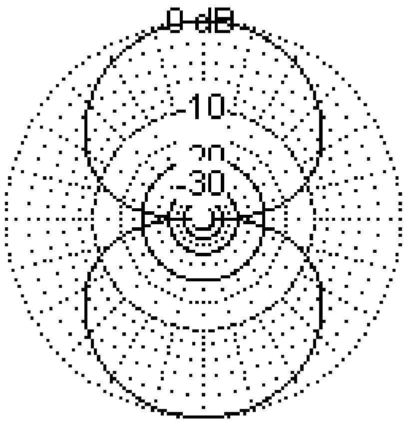
Dipole Characteristics

- **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 fictitious resistance that represents power flowing out of the antenna**
- **Radiation Pattern - the intensity of the radiated RF as a function of direction.**

The Short Dipole

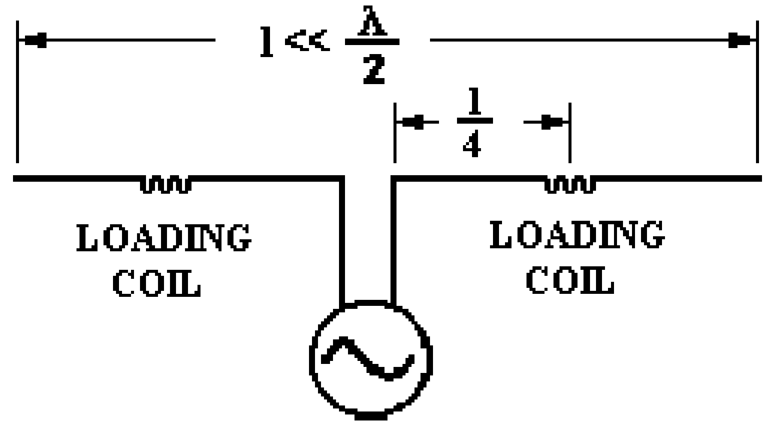
- The length is less than λ/2.
- The self impedance is generally capacitive.
- The radiation resistance is quite small and ohmic losses are high
- SWR bandwidth is quite small, ~ 2% of design frequency.
- Directivity is ~1.8 dBi. Radiation pattern resembles figure 8

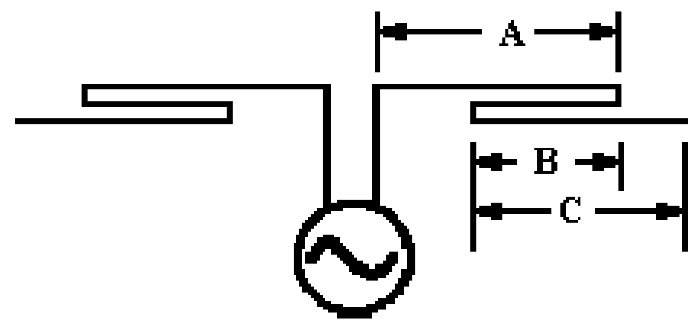




The Short Dipole

- 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
- 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

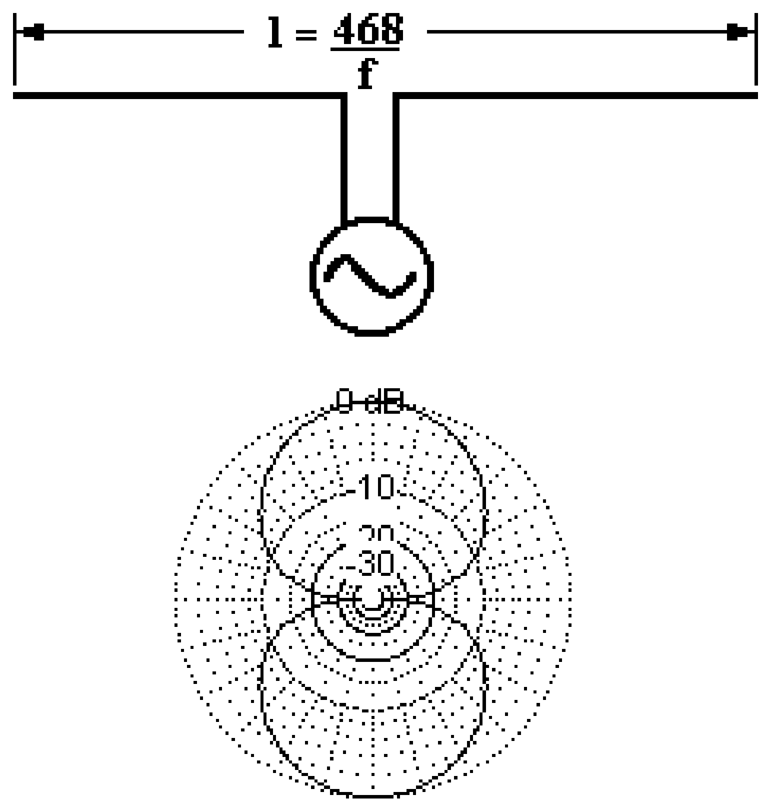
0.36 λ dipole with linear loading

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 (0.48 λ for wire dipoles)**
- **Self impedance is 40 - 70 ohms with no reactive component (good match to coax)**
- **Directivity ~ 2.1 dBi**
- **SWR Bandwidth is ~ 5% of design frequency**



Harmonic Operation of λ/2 Dipoles

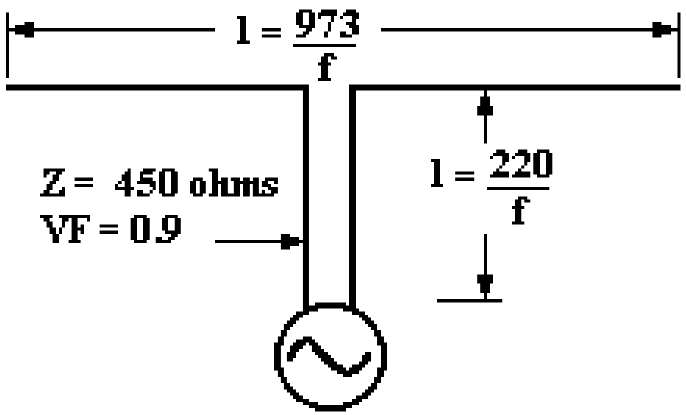
- A λ/2 dipole is also resonant at integral multiples of its resonant frequency.
- The self impedance of a λ/2 dipole at odd multiples of the resonant frequency is 100 - 150 ohms.
- The self impedance at even multiples is > 1000 ohms
- The directivity is never greater than the extended double Zepp.
-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

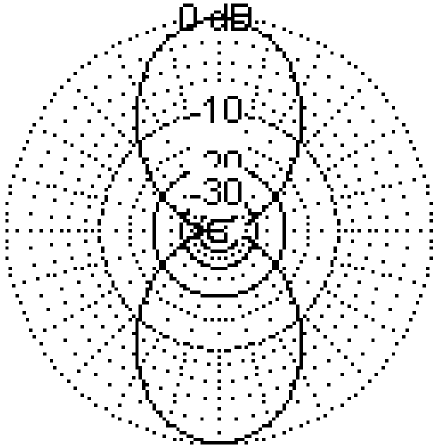
Design Table: Half Wave Dipole

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

The Full Wave Dipole (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



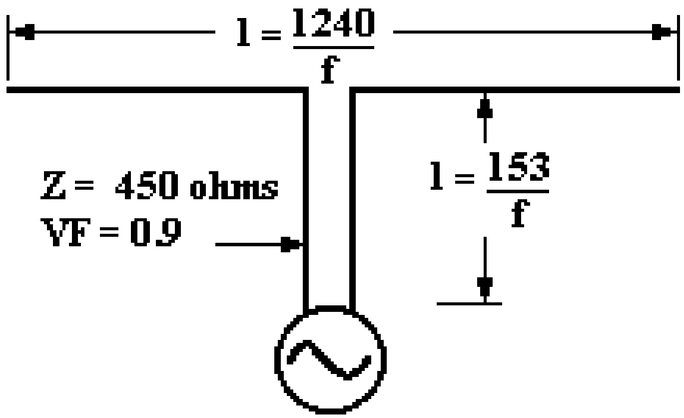


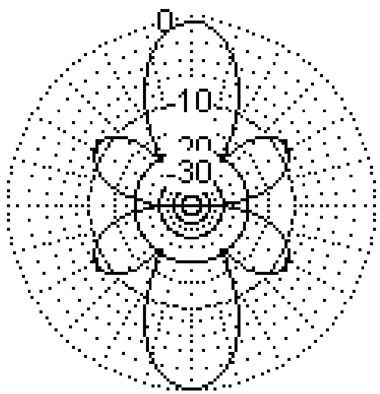
Design Table: Double Zepp

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



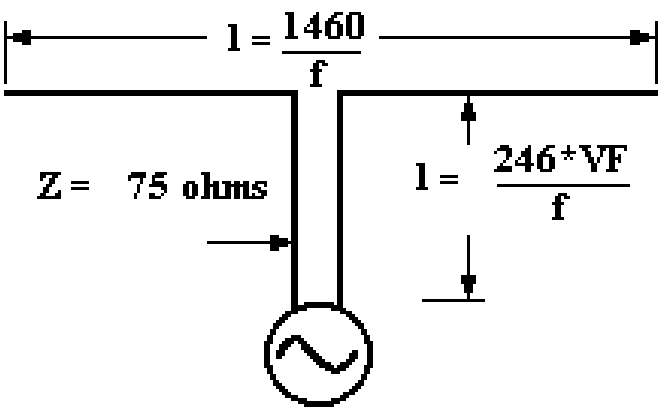


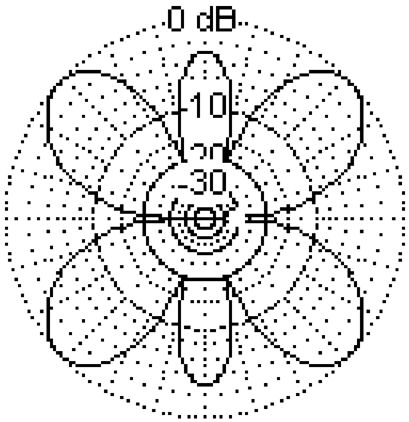
Design Table: Extended Double Zepp

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



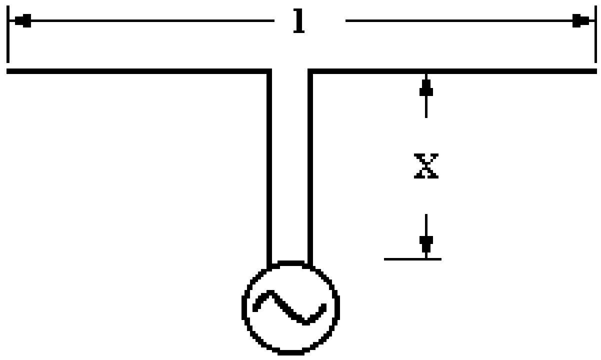


Design Table: 3λ/2 Dipole

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

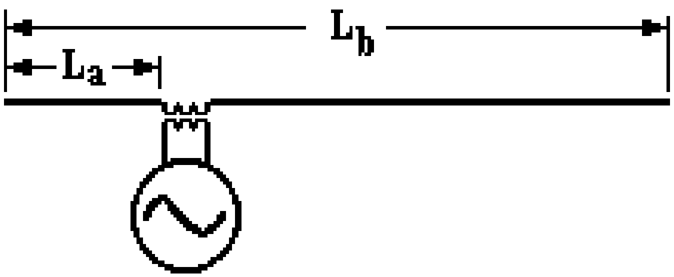


Design Table: Dual Band Dipole

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 (OCD)

- 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 OCD is > 100 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 towards away from the center, the impedance increases and the number of harmonics with low impedance resonance increases.

Design Table: OCD 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

Use of a dipole on several bands

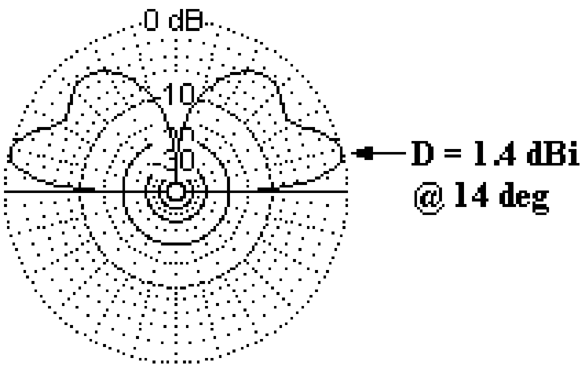
- It is possible to use a center fed dipole over a wide range of frequencies by:
  - feeding it with low-loss transmission line (ladder line)
  - providing impedance matching at the transceiver
- The lower frequency limit is set by the capability of the matching network. Typically a dipole can be used 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

The G5RV: what is it, really?

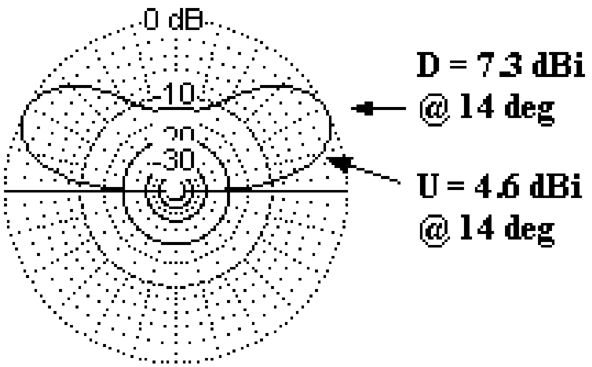
- The G5RV was originally designed as a 3 λ/2 antenna for use on 20 meters.
- It was used as a multi-band antenna because when fed with ladder line (not coax!) it is easy to match the on any band from 80m to 10m
- A G5RV used as a multi-band antenna should be fed with ladder line. Most commercially-made 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 λ/4 long at the lowest operating frequency.
- There is nothing magic about a G5RV. It is just a dipole

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



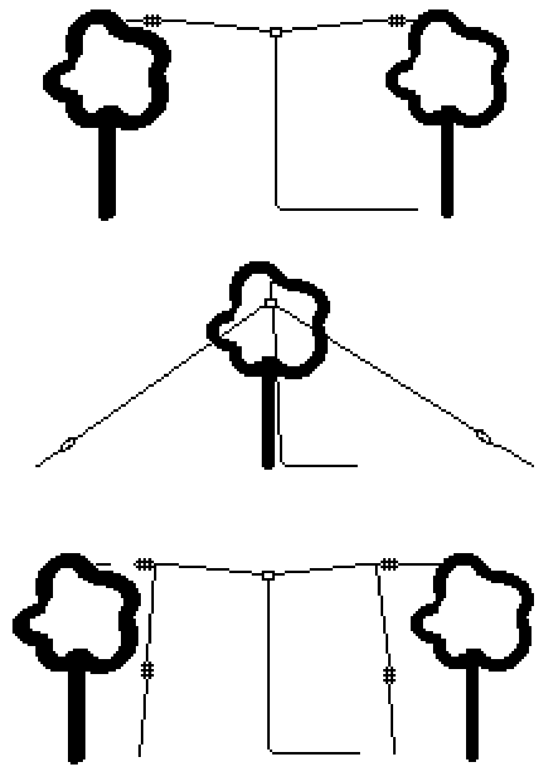
Vertical dipole ctr height = λ/2



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 should be at least half way to the end of the wire



Dipole 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**

Dipole 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

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**
- **The support should be tall enough that the dipole is at least 1/2 wavelength about the surrounding terrain ($\lambda/2 = 492/f$)**

Other useful information

- **Do not run a dipole above 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

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