BASIC ANTENNAS

What is an antenna?

- An antenna is a device that:
  - Converts RF power applied to its feed point into electromagnetic radiation.
  - Intercepts energy from a 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.

Important Antenna Parameters

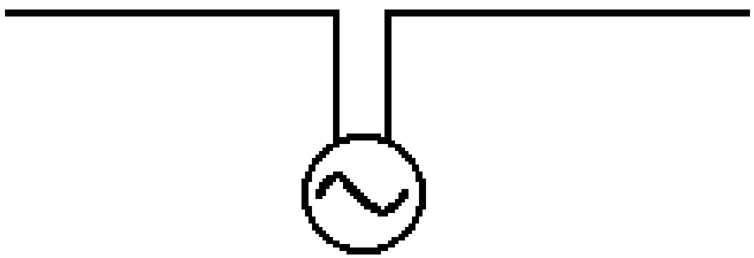
- **Directivity or Gain:**
  - Is the ratio of the power radiated by an antenna in its direction of maximum radiation to the power radiated by a reference antenna in the same direction.
  - Is measured in dBi (dB referenced to an isotropic antenna) or dBd (dB referenced to a half wavelength dipole)
- **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 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 SWR < 2:1

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 ~ $\lambda/2$ of the antenna. It temporarily stores power and is related to the imaginary term of the input impedance.
- The Far Field
  - An electromagnetic field launched by the antenna that extends throughout all space. This field transports power and is related to the radiation resistance of the antenna.

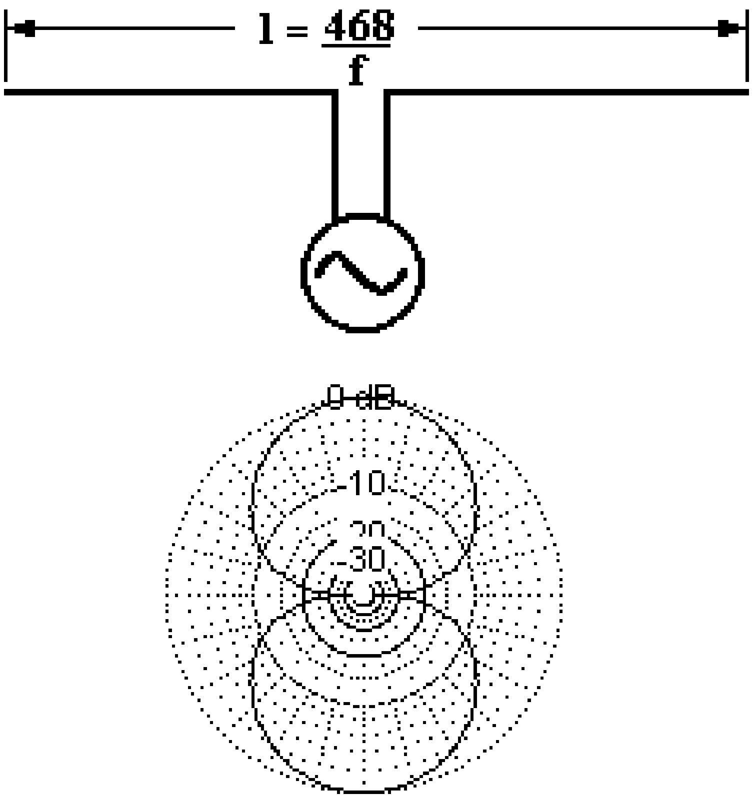
Dipole Fundamentals

- 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.



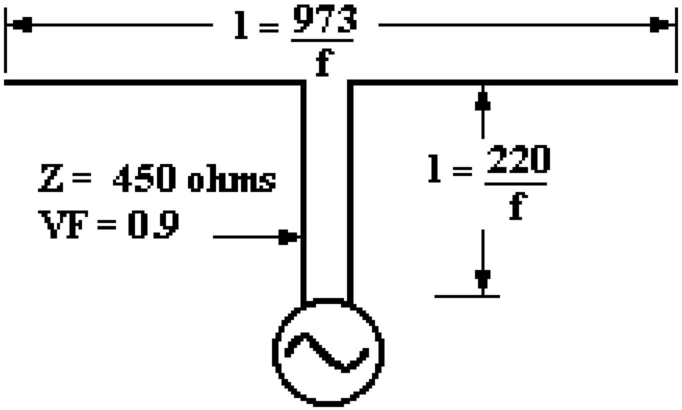
The Half Wave (λ/2) Dipole

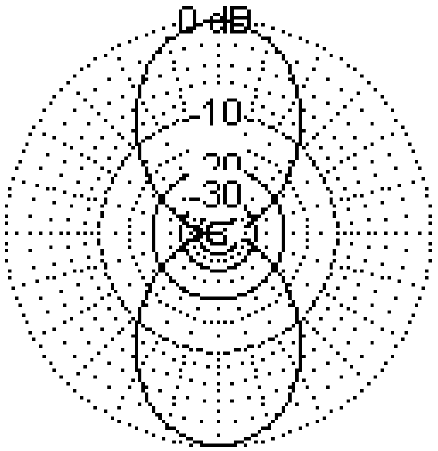
- Length is approximately λ/2 (0.48 λ for wire dipoles)
- Self impedance is 40 - 80 ohms with no reactive component (good match to coax)
- Directivity ~ 2.1 dBi
- SWR Bandwidth is ~ 5% of design frequency



The Double Zepp Antenna

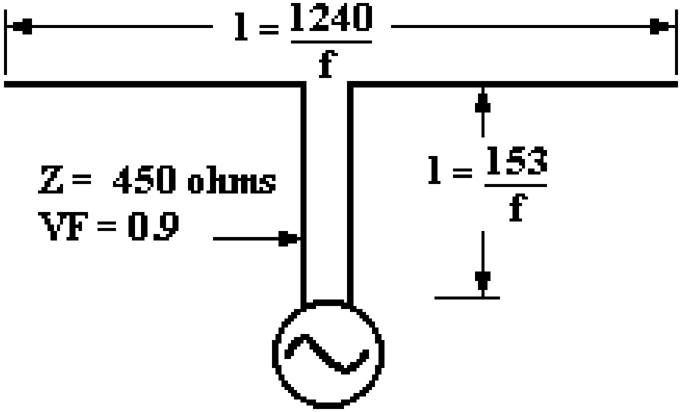
- A long dipole whose length is approximately 1λ
- Self impedance is ~ 3000 ohms.
- Antenna can be matched to coax with a 450 ohm series matching section
- Directivity ~ 3.8 dBi
- SWR Bandwidth ~ 5% of design frequency

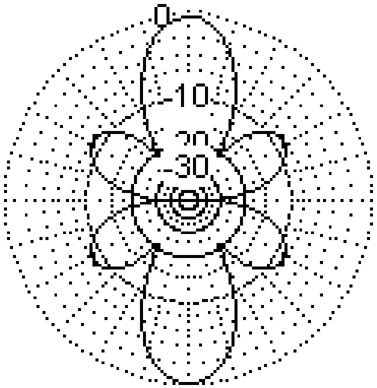




The Extended Double Zepp

- 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





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

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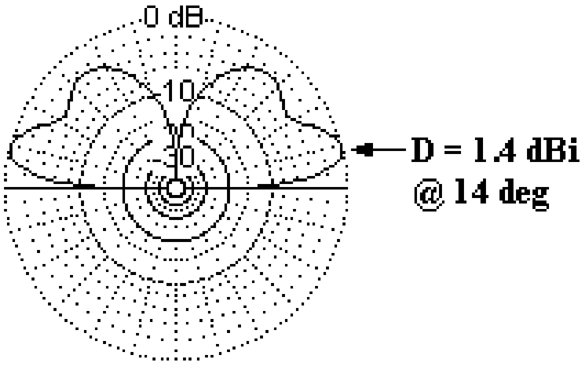
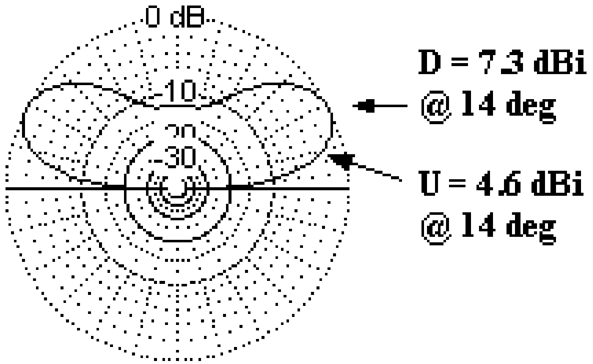
Dipole Polarization

- 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



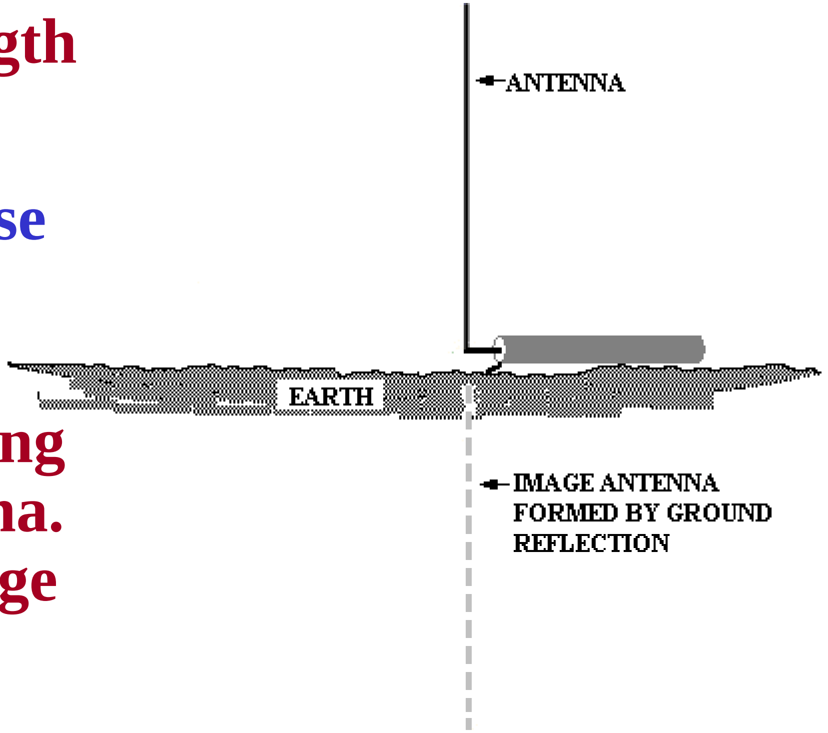
Vertical dipole ctr height = λ/2



Horizontal dipole height = λ/2

Vertical Fundamentals

- A vertical antenna consists of a single vertical radiating element located above a natural or artificial ground plane. Its length is < 0.64λ
- RF is generally fed into the base of the radiating element.
- The ground plane acts as an electromagnetic mirror, creating an image of the vertical antenna. Together the antenna and image for a virtual vertical dipole.



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 λ/4 long, and is ~ λ/3 out from the feed point for a λ/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.**

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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

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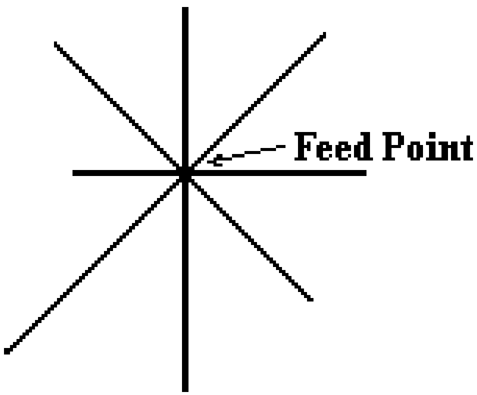
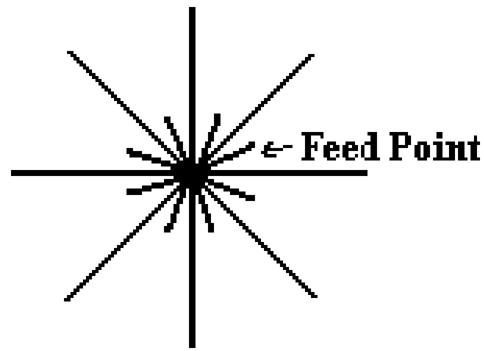
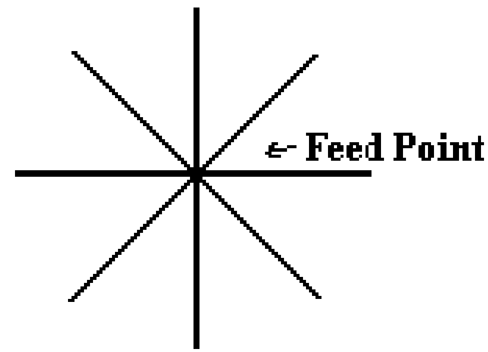
Radial/Counterpoise Layout



Ground Radial System
with random length
radials on ground



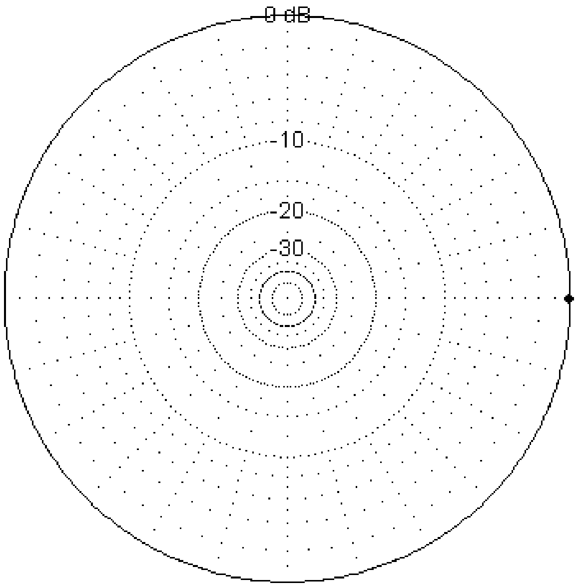
Ground Radial System
with extra short radials
in high current region



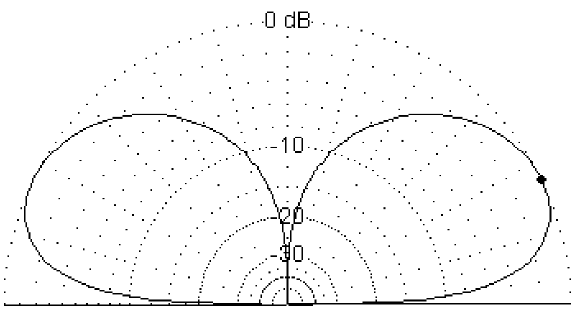
Elevated Counterpoise
using $\lambda/4$ radials

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



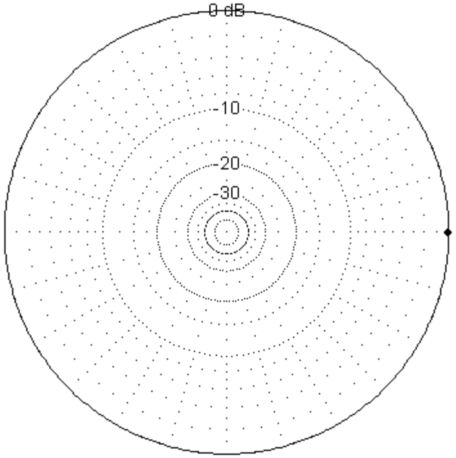
Azimuth Plot



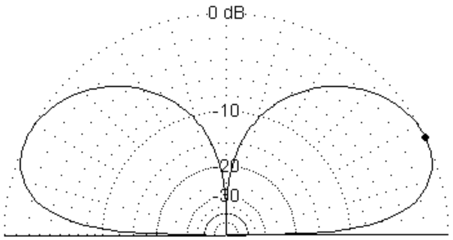
Elevation Plot

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



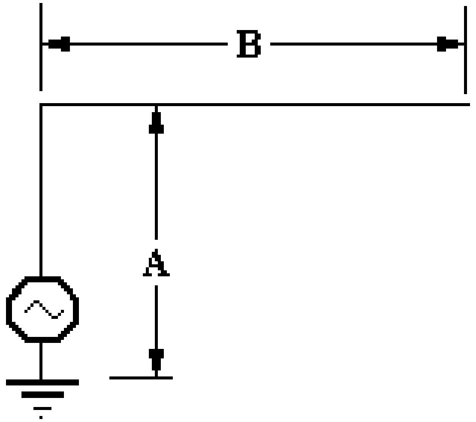
Azimuth Plot



Elevation Plot

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

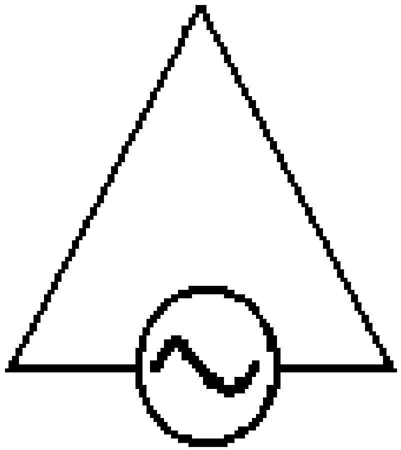


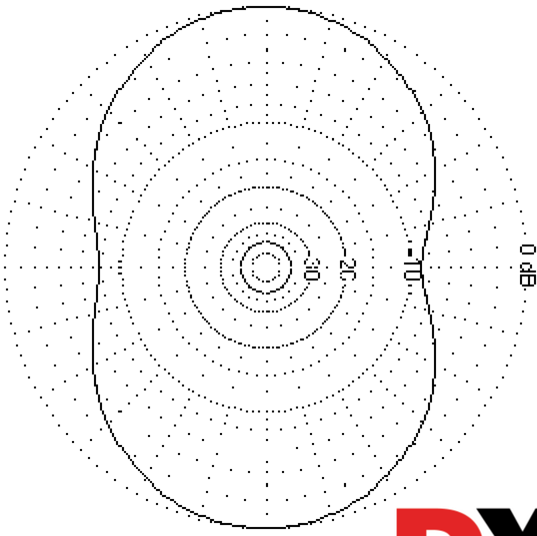
Use of a Vertical Monopole on several bands

- **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**

The Delta Loop

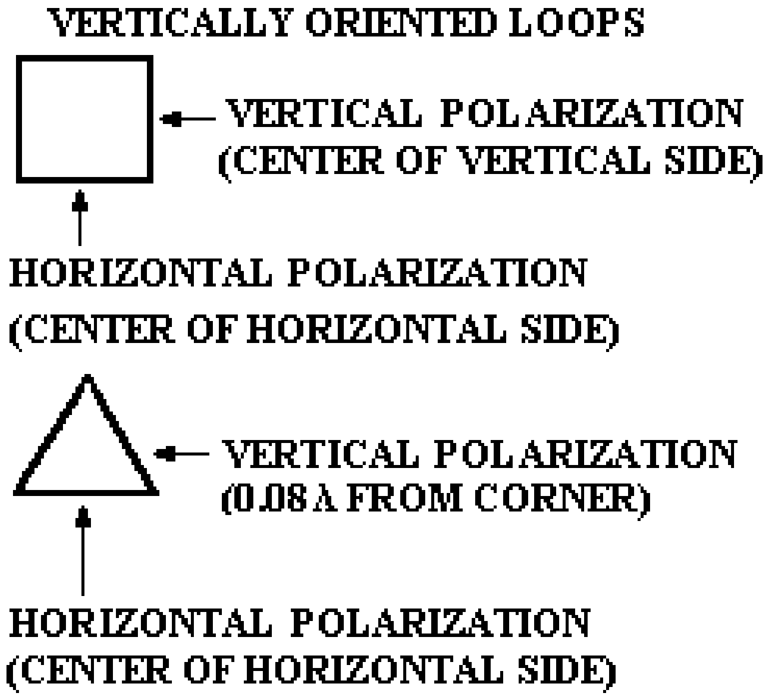
- A three sided loop is known as a delta loop.
- For best results, the lengths of the 3 sides should be approximately equal
- The self impedance is 90 - 110 Ω depending on height.
- Bandwidth ~ 4 %
- Directivity is ~2.7 dBi. Note that the radiation pattern has no nulls. Max radiation is broadside to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





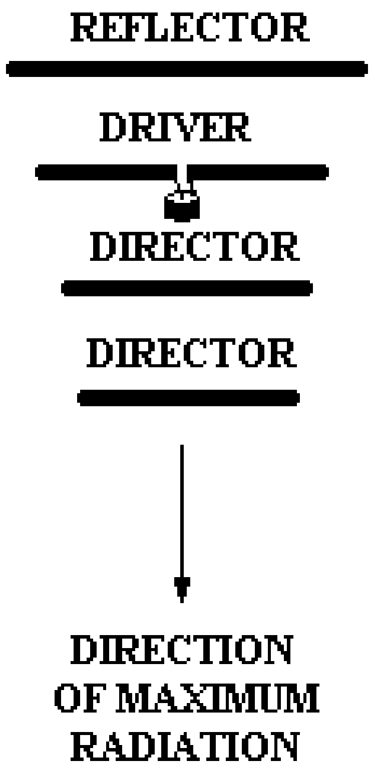
Polarization of Loop Antennas

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



Yagi Fundamentals

- A Yagi-Uda array consists of 2 or more simple antennas (elements) arranged in a line.
- The RF power is fed into only one of the antennas (elements), called the driver.
- Other elements get their RF power from the driver through mutual impedance.
- The largest element in the array is called the reflector.
- There may be one or more elements located on the opposite side of the driver from the reflector. These are directors.



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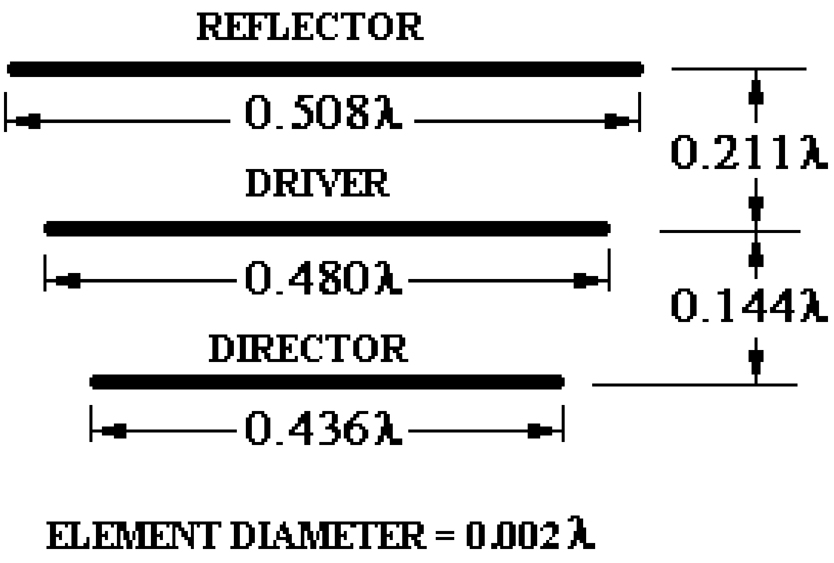
Yagi Array of Dipoles (yagi)

- This type of Yagi-Uda array uses dipole elements
- The reflector is ~ 5% longer than the driver.
- The driver is ~ 0.5λ long
- The first director ~ 5% shorter than the driver, and subsequent directors are progressively shorter
- Interelement spacings are 0.1 to 0.2 λ



Typical yagis (6 m and 10m)

The 2 element Yagi

- The parasitic element in a 2- element yagi may be a reflector or director
- Designs using a reflector have lower gain (~6.2 dBi) and poor FB(~10 dB), but higher input Z (32+j49 Ω)
- Designs using a director have higher gain (6.7 dBi) and good FB(~20 dB) but very low input Z (10 Ω)
- It is not possible simultaneously to have good Z_{in}, G and FB

The 3 element Yagi

- High gain designs (G~ 8 dBi) have narrow BW and low input Z
- Designs having good input Z have lower gain (~ 7 dBi), larger BW, and a longer boom.
- Either design can have FB > 20 dB over a limited frequency range
- It is possible to optimize any pair of of the parameters Z_{in}, G and FB

Larger yagis (N > 3)

- There are no simple yagi designs, beyond 2 or 3 element arrays.
- Given the large number of degrees of freedom, it is possible to optimize BW, FB, gain and sometimes control sidelobes through proper design. (although such designs are not obvious)
- Good yagi designs can be found in the ARRL Antenna Book, or can be created using antenna modeling software

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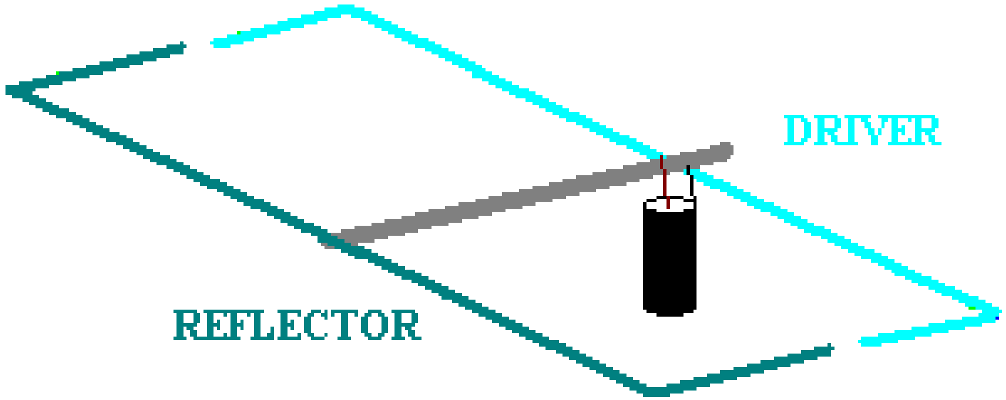
The Moxon Rectangle

- This is a 2-el Yagi-Uda array made from dipoles bent in the shape of a U
- The longer element is the reflector.
- The Input Z is 50 Ω – no matching network is needed.
- Gain ~ 6 dB, FB~ 25-30 dB (better than 2 el yagi or quad)
- More compact than yagi or quad
- Easily constructed from readily available materials



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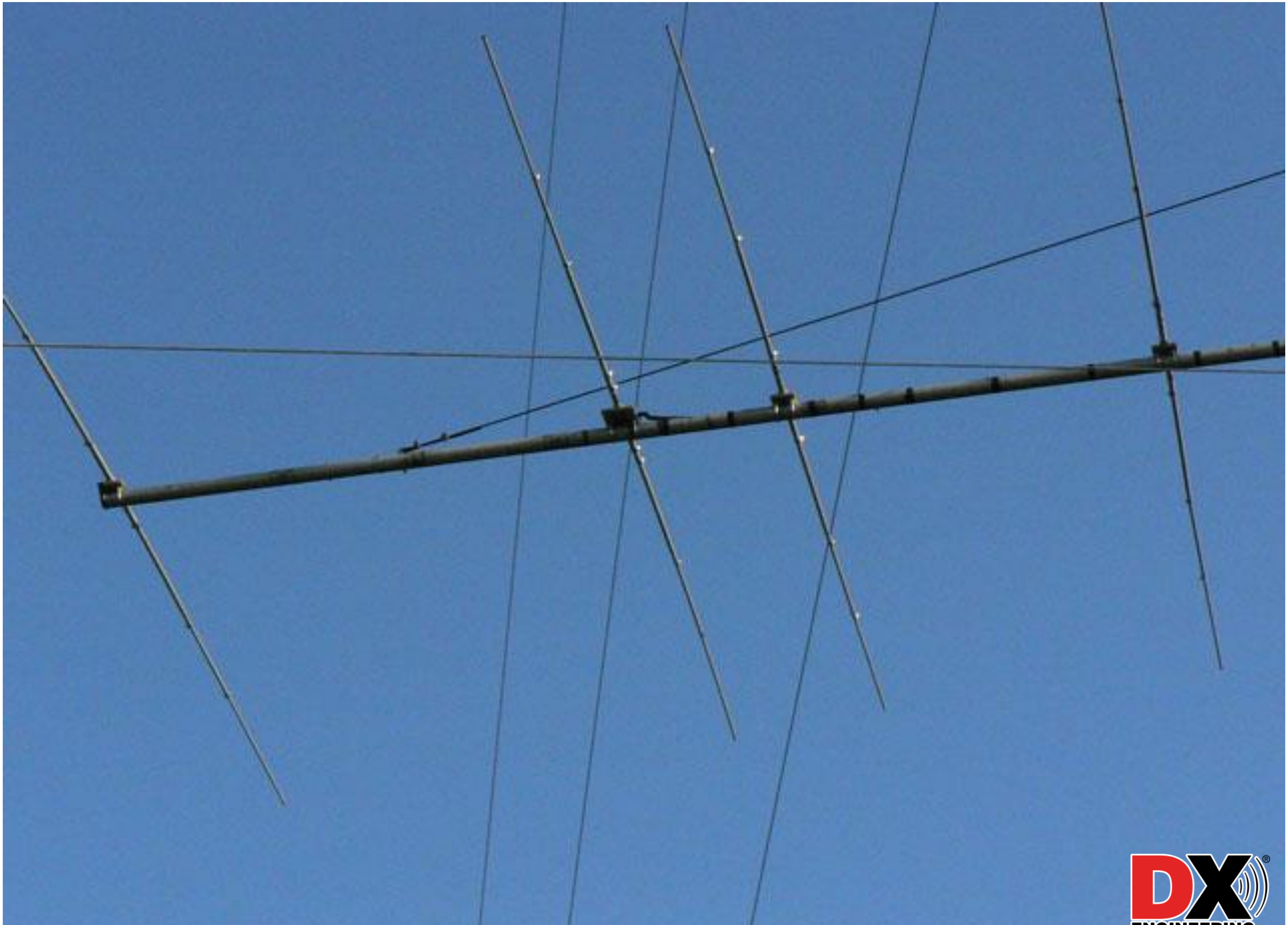
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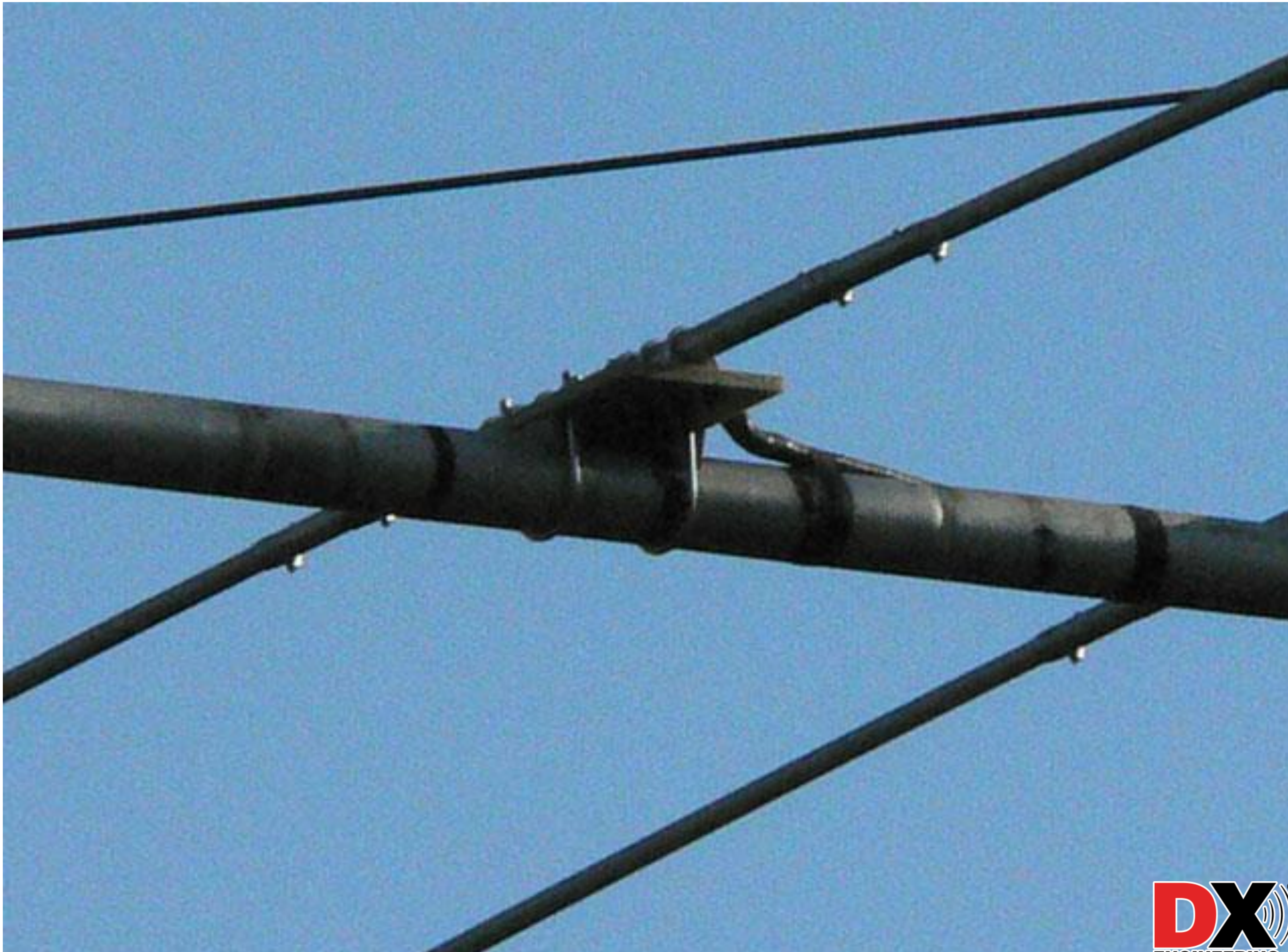
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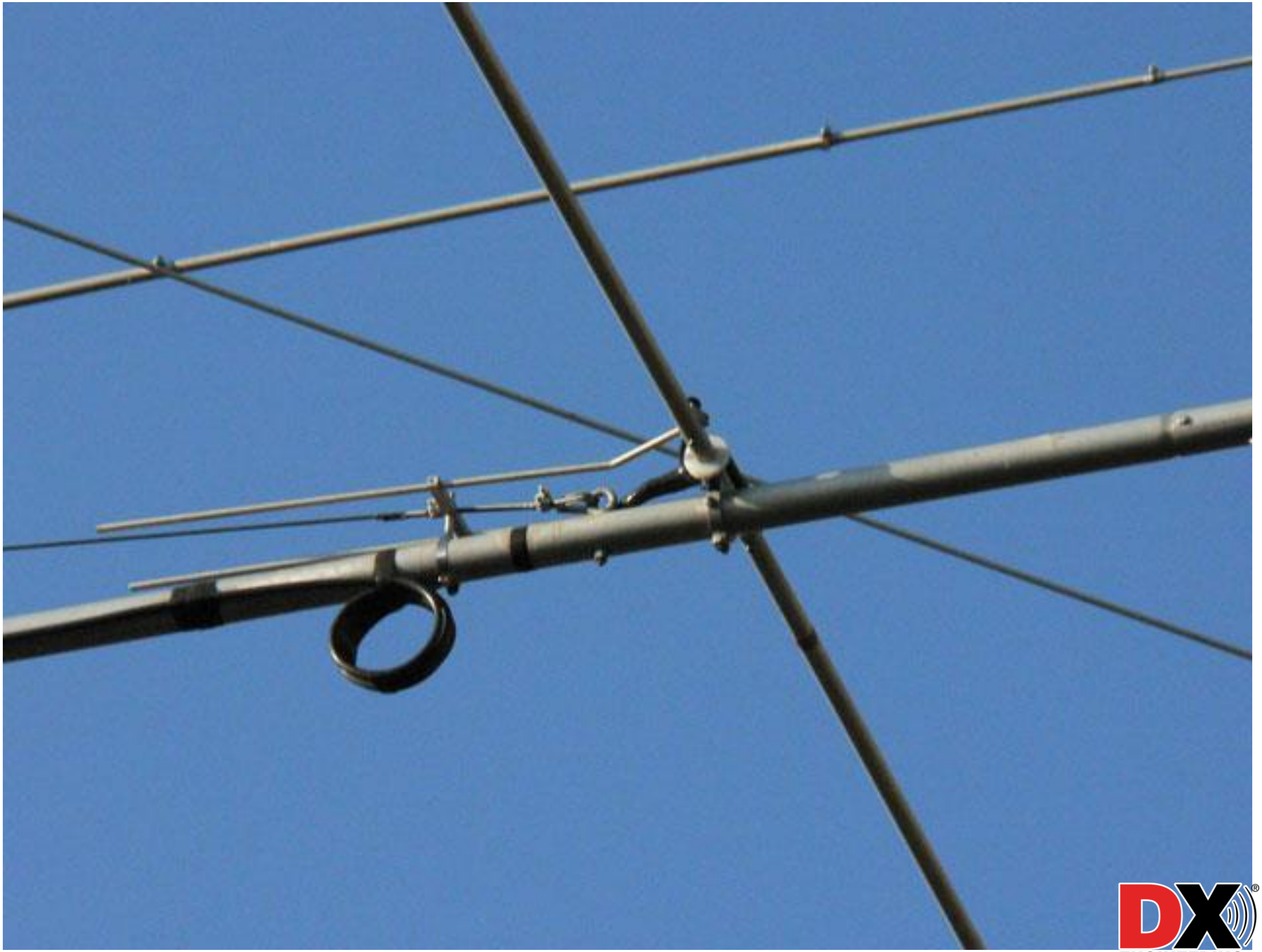

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