The Three L-Antennas

Wide – Equal - Tall

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A space saving antenna in the form of an upright L has been around the amateur radio world for a long time. References are found back to a QST article in the 60's (*Reference 1*), the ARRL Antenna Handbook in the 70's through 90's (*Reference 2*) and to L. B. Cebik's (*References 3,4*) and Craig LaBarge's (*Reference 5*) writings in recent years. Commercial designs are seen in the Buddipole ™ (*Reference 6*), MFJ-1790 (*Reference 7*) and the CrankIR antennas (*Reference 8*). By the use of antenna modeling software (*Reference 10*), this article is to expand our general knowledge relative to angle-of-bend and off-center-feed (OCF) configurations of the L-Antenna.

The L-Antenna

So simple. So easy to tune. Just hang up a wire or put up a pole and run another adjustable length wire or pole off to the side. Connect your coax at the bend. It really does not matter how you connect the coax. It really does not matter how long is the vertical arm. Simply tune by adjusting the length of the side arm. The total length of the two arms will end up around a half wavelength.

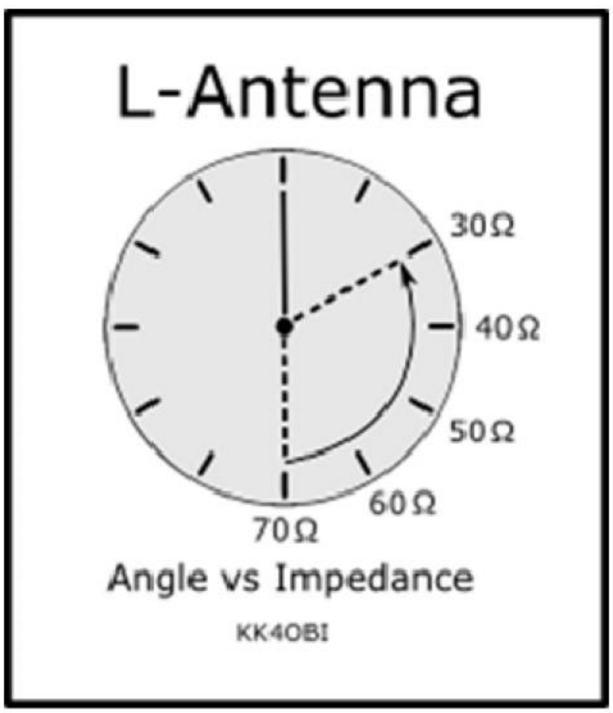

Figure 1
Angle Vs Impedance for L- Antenna

The L-antenna can be looked at as a center-fed dipole bent in the middle or… a vertical monopole with a single radial. At an elevation one-half wavelength a straight vertical dipole has about 1.6 dBi gain (decibel isotropic). The L form however has gain around 4 dBi in the direction where the radial is pointing. Depending on ground conditions and mounting height, the impedance is around 40 ohms making the configuration a decent match for 50 ohm coaxial cable.

Since the impedance of a vertical dipole is around 70 ohms, there obviously is a 50 ohm point somewhere between 0° down and a bend of 90° horizontal… usually near 75° (or 15° below horizontal). Gain at this point is around 3 dBi.

Interestingly, as the arm/radial continues to be raised above horizontal, the impedance declines to around 30 ohms, the Standing Wave Ratio (SWR) approaches 2:1 but the gain of the vertical monopole increases up to 5 dBi…. *several times the gain of a vertical dipole.*

Off-Center-Feed (OCF)

In practice and in antenna modeling studies it is observed that the impedance of a horizontal dipole rises as the feed point moves away from center. Resonant frequency and gain remain the same. *Just impedance changes*. This technique is used when tuning low-impedance antennas like a J-Pole or when using a Gamma Match or Delta Match on multi-element beams. Tall ground plane antennas with short radials are also off-center designs.

Figure 2 following is a generalized impedance graph of what happens when feeding off-center.

Question: If an antenna has low impedance fed at the mid-point, where is 50 ohms? For example, a half-wave at 10 meters is 5 meters long. From the graph the usual OCF ratio of 0.67 (2/3) looks like a good guess for a starting point. That means we start with one arm at 0.67 x 5 meters = 3.35 meters long. The other arm is 5 meters minus 3.35 = 1.65 meters long.

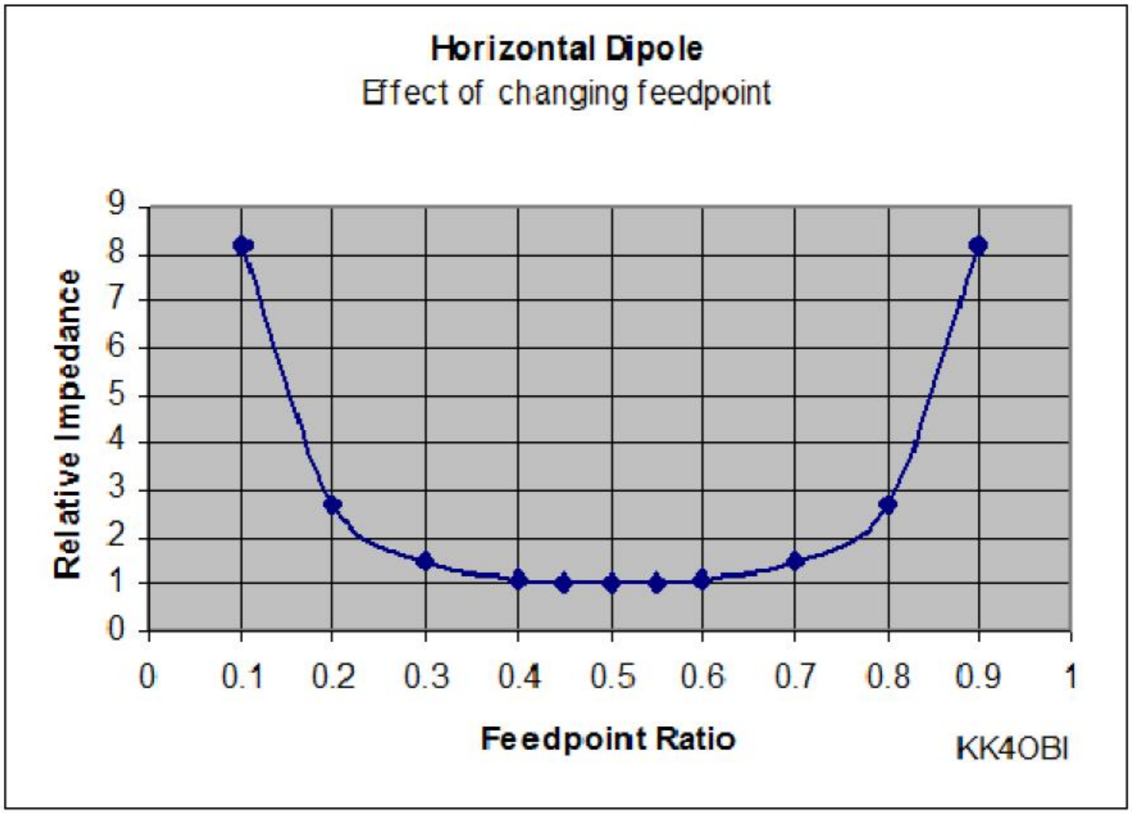

Figure 2
Generalized Impedance Graph for Off Center Dipole Antenna

Tuning: If the impedance is high at 0.67, the ratio is high. If the impedance is low, the ratio is low. Adjust accordingly. *Simple!*

Advice: Use a *choke balun* at the feedpoint. The farther off-center, the greater the current imbalance between arms, the more "common mode" current on a coaxial feed line. Common mode current problems cause change in tuning if you touch the cable, sometimes tingling or "bites" to face and lips when transmitting. RF radiating from the coax can couple with nearby electronics or AC power lines to affect TV, radios, clocks as well as control devices like alarms, thermostats and monitors.

Equal, Wide and Tall L-Antennas

The Equal L-Antenna

With "equal" arms, the horizontal arm is slightly longer at resonance due to the effect of ground. The arm-to-arm ratio therefore is not exactly 0.5. Impedance is around 40 ohms. SWR can be as low as 1.2-1.3:1. RF polarization is equally horizontal and vertical.

The principles of OCF apply very well for L-antennas. The Wide or Vertical characteristic can emphasized by making OCF ratios smaller or larger.

The Wide L-Antenna

As the off-center feedpoint ratio goes <u>less than</u> 0.5, the L-antenna becomes wider and the impedance rises towards 50 Ohms. The antenna hears and talks more like a *<u>horizontal dipole</u>* as the SWR approaches 1:1.

The Tall L-Antenna

As the off-center feedpoint ratio goes <u>greater than</u> 0.5, the L-Antenna becomes taller and the impedance rises towards 50 Oms. It hears and talks more like a *<u>vertical antenna</u>* as the SWR approaches 1:1.

Based on modeling software, **Figure** 3 below summarizes the results as the feedpoint of an L-Antenna is changed by 0.05 (5%) increments around the center 0.50 ratio.

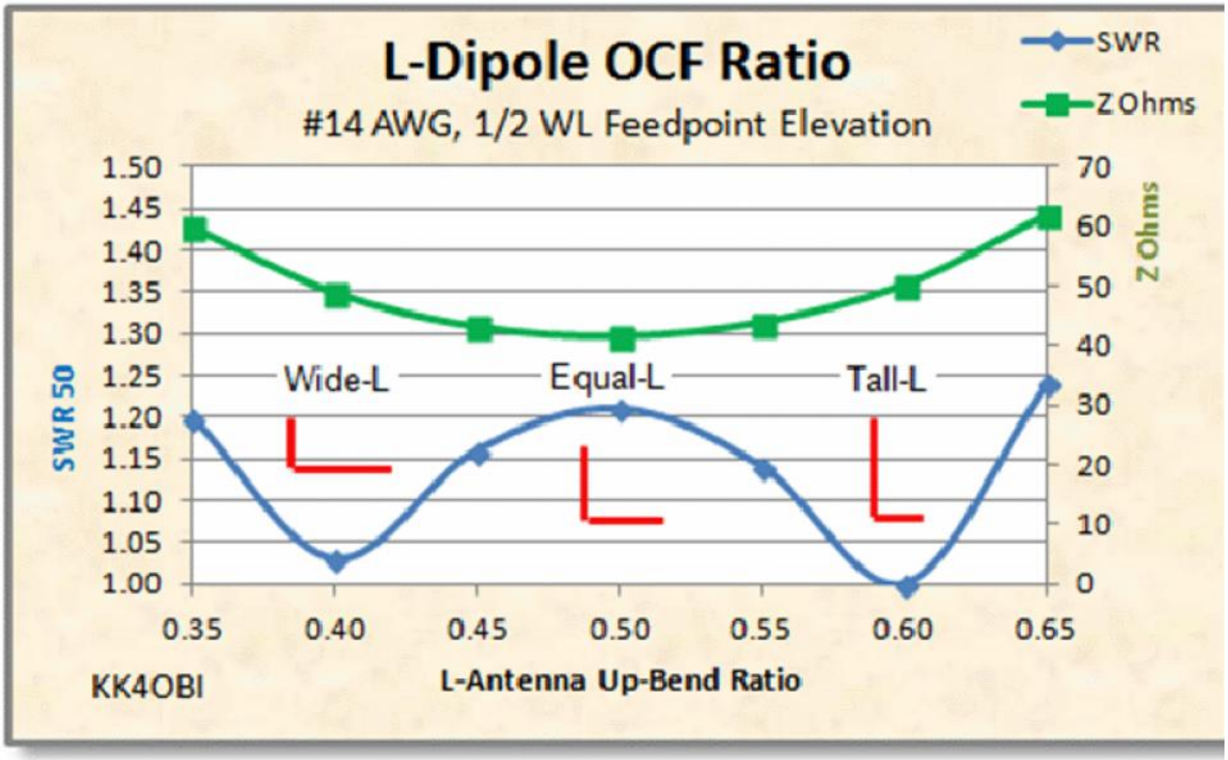

Figure 3

Summarizing the Results as the Feedpoint of an L-Antenna is Changed by 0.05 (5%) Increments Around the Center 0.50 ratio

It is clear that an L-Antenna is easy to tune at any up-bend ratio between about 0.35 and 0.65; and with effort, out to a 0.25 or 0.75 ratio.
For hams wishing to fine-tune their L-Antennas, 0.40 and 0.60 are the magic points.

Note that there is an impedance effect caused by ground coupling as the horizontal arm gets longer. The Wide L-Antenna cannot quite get to a 1:1 SWR.

Of particular interest is that L-antennas have both vertical and horizontal polarization. The ARRL Antenna Book says: *"Some immunity from fading during reception can be had by using two receivers on separate antenna, preferably with different polarizations*" (**Reference 9**).

In this case there are different polarizations on one antenna. The resulting effect of reduced fading can be heard on DX signals by switching between an L-Antenna and a conventional dipole. For nearby communications, an L-Antenna makes all the difference in hitting repeaters and talking to hams with verticals, dipoles or yagis.

The Tall-L Antenna

When the vertical arm is tall, the length of a 90° side arm can be adjusted to resonate the antenna to the desired frequency. The SWR match of a Tall-L antenns can be better than the Equal-L Antenna. Depending on elevation, ground and diameter of the wires or tubes used, there will be some ratio between the length of the vertical and horizontal arms that will give the best match to a 50 ohm coaxial cable. Anywhere up to a 2/3 up-bend ratio works. Understanding this you can easily tune any vertical radiator. The total length will always be about ½ wavelength.

This tall L-configuration has the distinct functions of a vertical in that it is generally quieter than a dipole and performs well for DX. It can be a good choice when listening around the band.

It has another notable feature. It develops a horizontal component from the side arm. This gives some directionality and gain over a simple vertical antenna. The directionality is a bit more broadside to the side arm but generally semi-circular as seen in **Figure 5**. The angle of the side arm can be used for tuning using ratios as tall as a 3/4 up-bend . Ratio and arm angle influence the direction of maximum gain.

Modeling

Antenna modeling software can optimize a vertical dipole into the tall OCF form.

Using that capability, **Figure 4** below shows what happens to a Tall OCF dipole as the shorter lower arm is swung upwards in 15° increments from 0° (down), to 90° (horizontal), to 150° (60° up).

Standard conditions are: 2/3-1/3 ratio, #14 AWG, ½ wavelength feedpoint elevation, over “real ground”.

- The lowest SWR occurs with the variable arm at 105°… 15° above horizontal.
- The gain of the Tall-L Antenna is over twice that of the OCF vertical dipole at 0°.

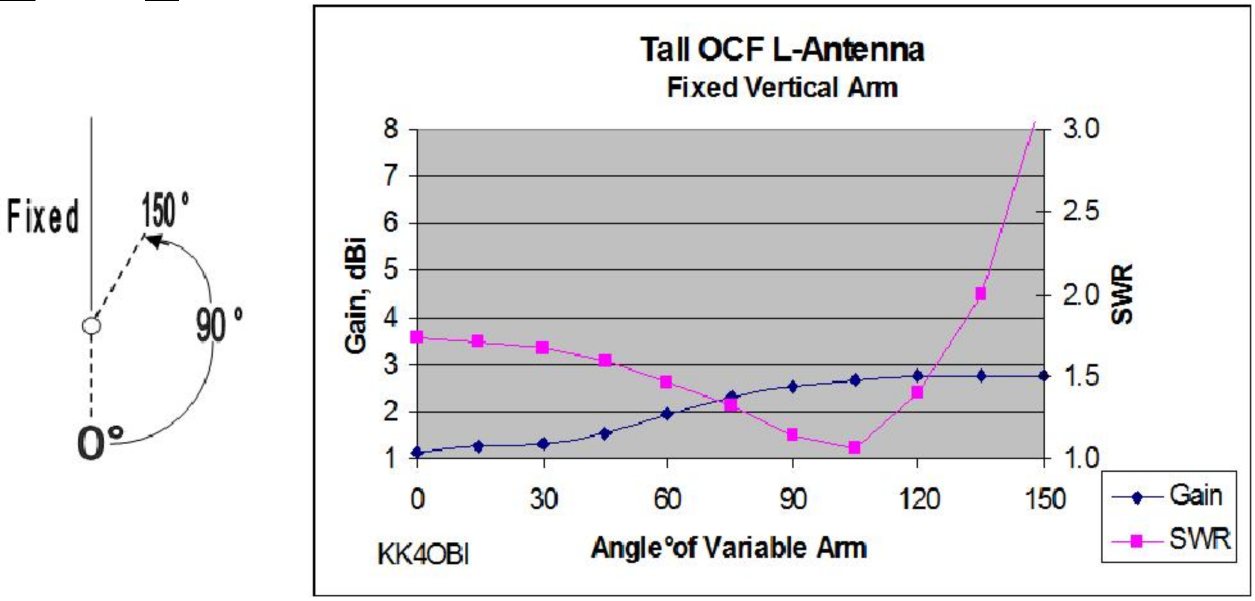

Figure 4

SWR and Gain at Tal OCF Dipole when Shorter Lower Arm is Swung Upwards

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Model Example (Figure 5)

Conditions: 4NEC2 software (**Reference 10**) model of a Tall-L Antenna, fed at ½ wavelength over real ground using #14 wire, optimized at 28.4 MHz.
Predicted dimensions: Vertical arm: 3.147 meters tall; Horizontal arm: 2.08 meters long.
Total length: 5.227 meters at 60-40 ratio.
Impedance: 50.5 –j0.43; SWR: 1.01; Gain: 2.69 dBi

At ***page 16*** is the 3D view and horizontal/vertical polar graph produced by the model.

Note: the radiation pattern is 2.69 dBi on the hemisphere towards the side arm. The opposite side has 0.01 dBi gain therefore signals are about half as loud from the back hemisphere. Compare this with an omni-directional 1.5 dBi circle which is the norm for a vertical antenna.

Observe the 10-degree low angle radiation for DX and the stronger signal at a 40-degree upward angle. No energy is wasted skyward.

This is a good configuration for general, all-around band scanning because it will hear polarized signals that might otherwise be too weak.

If a second horizontal arm is added at 180° opposite and both are tuned by length to the desired frequency, the radiation field balances. The radiation pattern becomes circular and the antenna becomes a tall ground plane vertical.

The MFJ-1790 10 meter antenna (**Reference 7**) is an example. It has an 11-foot vertical and two 6-foot radials to give "Low Radiation Angle for outstanding DX".

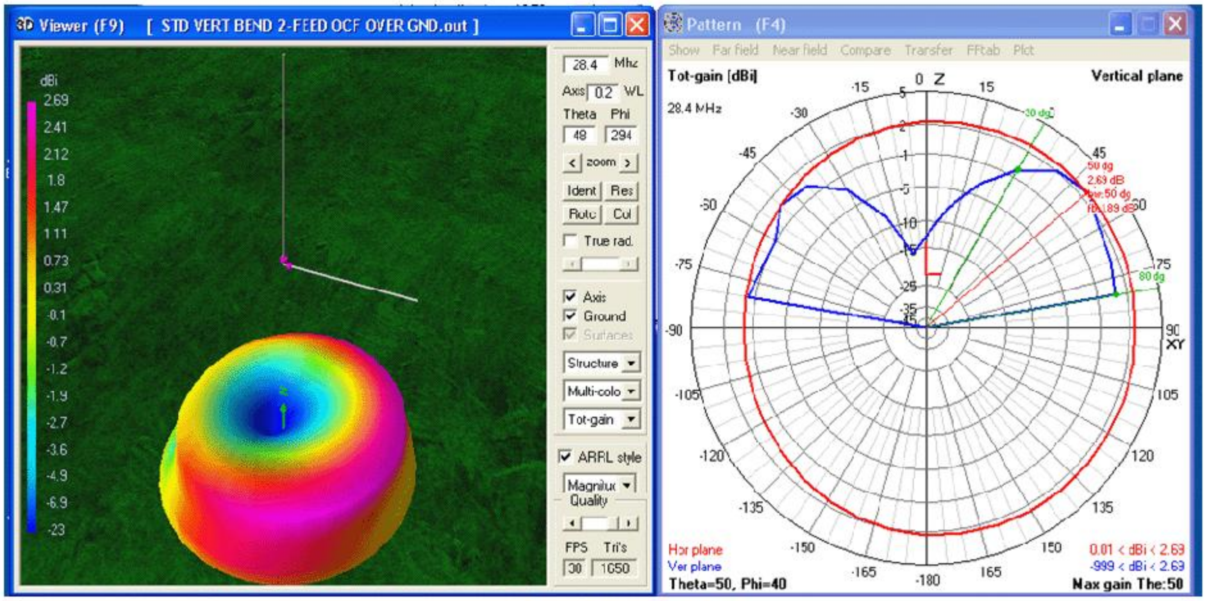


Figure 5

Tall L-Dipole

The Wide L-Antenna

When the vertical arm is short, the length of a 90° side arm can be adjusted to resonate the antenna to the desired frequency. The SWR match can be better than the Equal-L Antenna. Depending on elevation, ground and diameter of the wires or tubes used, there will some ratio between the length of the vertical and horizontal arms that will give a nearly perfect match to a 50 ohm coaxial cable.

This Wide-L configuration has the characteristic of being shorter than a halfwave dipole with nearly the same gain.

Having both horizontal and vertical polarization, it is less effected by undulations in DX skip reflections (QSB) than a conventional dipole.

Antenna modeling software can optimize a vertical dipole for the best wide OFC ratio at 1/2-wavelength feedpoint elevation over ground. Using that capability, **Figure 6** below shows what happens with a 2/3-1/3 ratio as the longer lower arm is swung upwards in 15° increments.

Note that the best SWR and Gain combination occurs at around 105, or 15° above horizontal.
This compares favorably with the gain of a center-fed dipole using the same wire and fed at the same elevation over the same ground.

http://qsl.net/kk4obi/

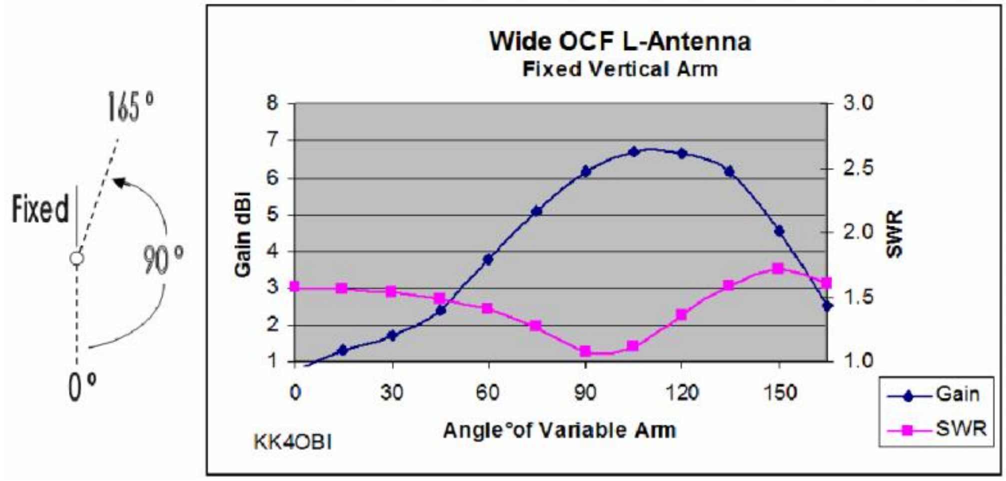


Figure 6

SWR and Gain at Wide OCF Dipole when Lower Arm is Swung Upwards

Model Example (Figure 7)

Conditions: 4NEC2 software model (**Reference 10**) of a Wide-L Antenna, fed at ½ wavelength over ground using #14 wire, optimized for 90° at 28.4 MHz are:
Predicted dimensions: Vertical arm: 2.083 meters tall; Horizontal arm: 3.1596 meters long.
Total length: 5.243 meters at 60-40 ratio.
Impedance: 49.3–j0.12; SWR: 1.01; Gain: 5.88 dBi.

Below is the 3D view and horizontal/vertical polar graph produced by the model.

- Like a dipole, the Wide-L antenna is directional to the side of the horizontal arm.
- The radiation pattern differs slightly from an ordinary dipole because there is no dip on one side of the horizontal (red line) radiation pattern.
- The Tall and Wide optimized models have similar dimensions for the short and long arms. A Tall-L antenna basically becomes a Wide-L Antenna when laid on its side.

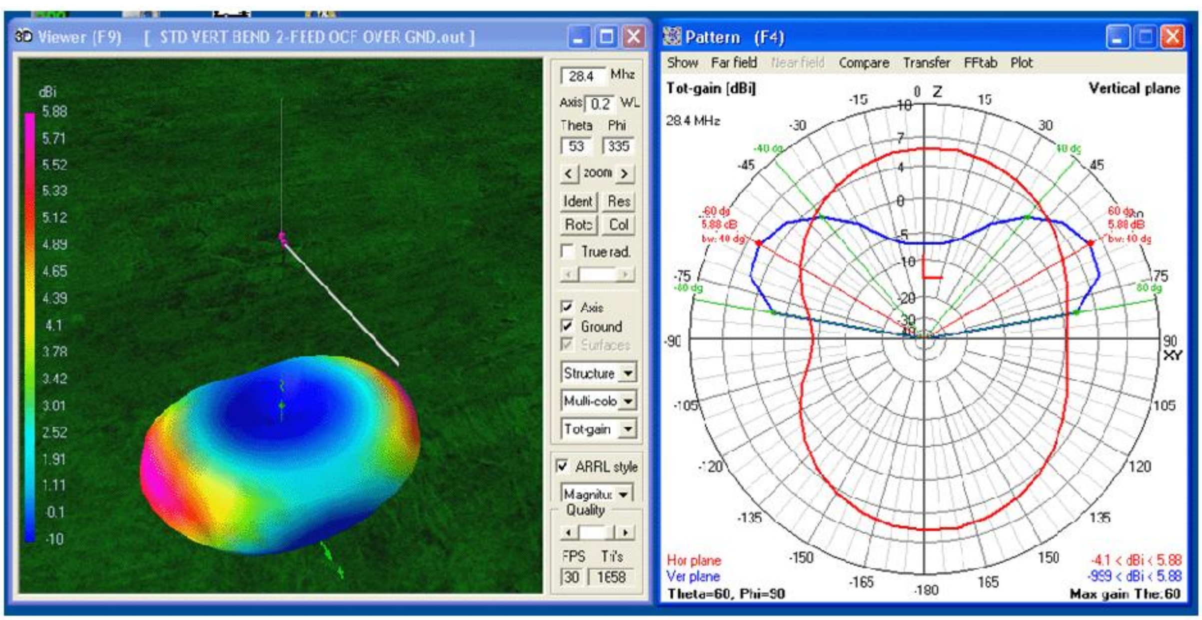


Figure 7

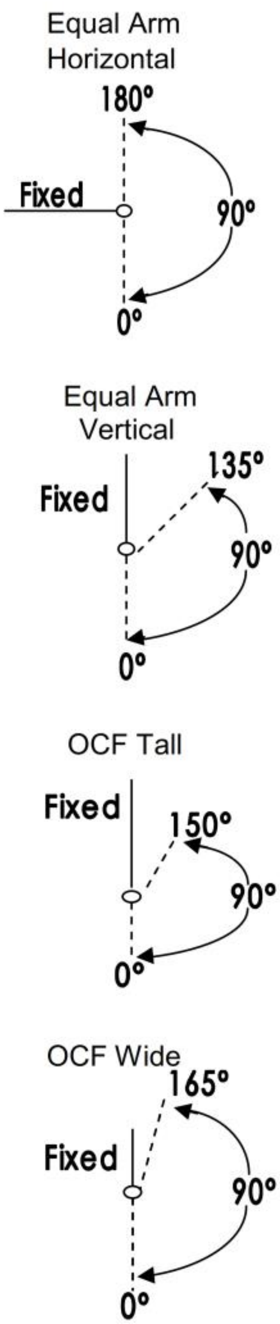
Wide L-Dipole

Summary

The following two graphs (***Figures 8 and 9***) compare the **Relative Gain** and **% Radiation Efficiency** of four kinds of dipoles, each as one of the antenna arms is adjusted through a range of angles.

All feedpoints at ½ wavelength elevation.
Plots stop at the point where the SWR exceeds 2:1.
OCF used is a 1/3-2/3 ratio.

1. Equal-arm Horizontal (dark line, diamond marker). 90° = standard horizontal dipole.
2. Equal-arm Vertical (violet line, square marker). 0° = standard vertical dipole.
3. OCF Tall (blue line, triangle marker). 90° = Tall L-Antenna.
4. OCF Wide (red line, X marker). 90° = Wide L-Antenna



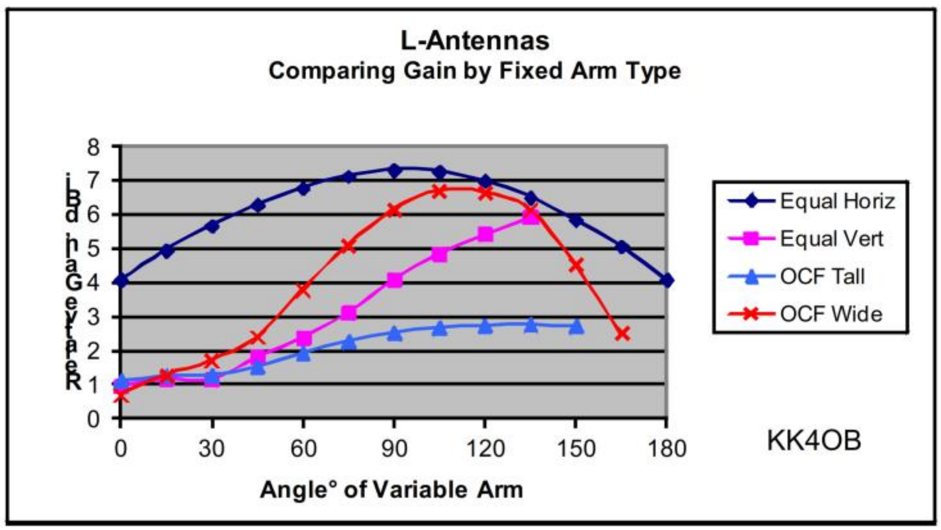


Figure 8 **dBi Gain vs Angle**

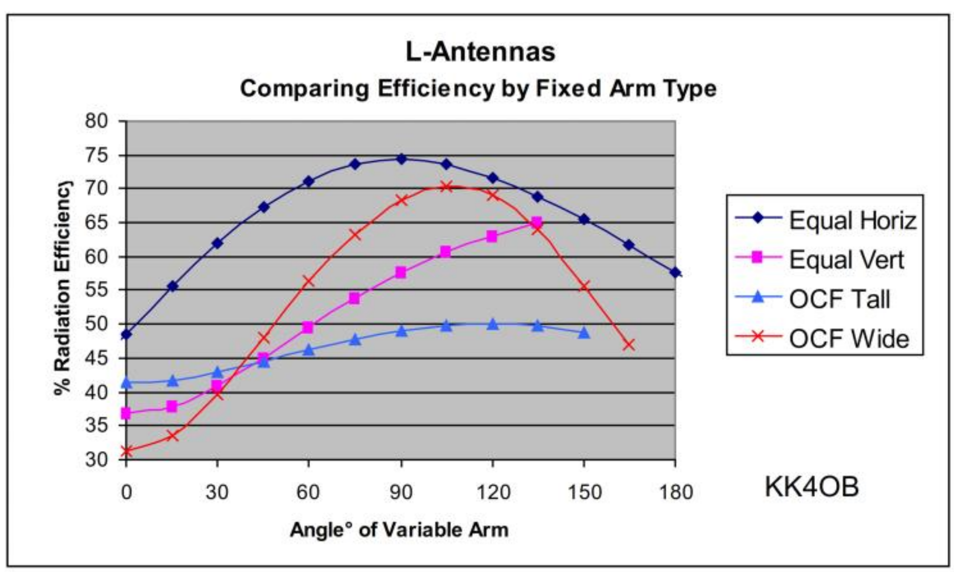


Figure 9 **% Radiation Efficiency vs Angle**

Conclusions:

- The **Wide L-antenna** is a shortened horizontal dipole that can come close to having the gain and efficiency of a conventional horizontal, center-fed dipole
- The **Tall L-antenna** performs much like a vertical but with some gain towards the side arm.
- The **Equal L- antenna** is part- vertical and part- dipole and can favor either type by changing the angle of the side arm.

All three forms are suitable for limited space environments and have a degree vertical and horizontal polarization which helps in both local and long distance communication.

Wire Antenna Modeling Software

This study answers the questions of what happens when you bend a dipole at different angles and feed it at different points.

It is unlikely an average amateur radio operator would have the time and resources to do this study by building prototypes even if he had the desire. With modeling software a ham can do in a few hours or days what would otherwise take weeks or months, if ever.

The results by way of software reveal how the changes in an antenna affect frequency, impedance, radiation pattern and other characteristics. Through optimization, modeling predicts the dimensions and angles that will give the best SWR, Gain or Efficiency.

There is a catch. Modeling software lives in its own perfect little world inside the computer. It works with the information given. The more sophisticated the program and the user, the better the results. In the real world we take guidance from the results but understand there will be differences in materials, design, construction, support structures and effects from near by things.

Modeling eliminates dead-ends, gives ideas and guides us to a working antenna.

References:

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5. LaBarge, Craig, WB3GCK, “The ‘Up and Outer‘ Antenna” www.qst.net/wb3gck/up_and_outer.htm
6. Buddipole, Inc. 3028 SE 59th Ct. #600, Hillsboro, OR 97123
7. MFJ Enterprises, Inc., 300 Industrial Park Road, Starkville, MS 39759
8. SteppIR Antennas,2112 116th Ave. NE, #1-5, Bellevue, WA 98004
9. “The ARRL Antenna Book”, 22nd edition, pg. 4.2.14
10. Free antenna modeling program by Arie Voors. www.qsl.net/4nec2/

73! de Dick Reid, KK4OBI

From Dick: If you are interested in what happens to a radiation pattern if you bend a dipole into an L, or a V, U... side-to-side, up-or-down... zig-zag, meander, off-center, elevated radials, etc... my QSL website about Bent Dipoles is the place to go. **www/qsl.net/kk4obi**

There are over thirty variations on ways to put up a dipole in limited space along with color 3D radiation patterns and details about the change in radiation characteristics, gain/SWR/impedance/efficiency/resonant length, etc.

For modelers the 4NEC2 software models are provided for each type of bent antenna. This allows an antenna model to be adjusted to represent your specific situation.