RADIAL SYSTEMS FOR ELEVATED AND GROUND MOUNTED VERTICAL ANTENNAS

By Mike Mertel K7IR

All vertical monopoles need some form of counterpoise in which antenna image currents flow to work efficiently. This counterpoise usually consists of a system of radial wires placed either on the ground or elevated above ground.

This is not an in-depth publication but simply a general guide on installing and using SteppIR verticals. There is much more information available in various publications if you need it. The ARRL Antenna Handbook is a good source for additional information. Rudy Severns, N6LF, has some excellent technical articles about radial systems on his website at antennasbyn6lf.com. In the following pages I will attempt to condense all of the experts advice into information you can easily use to make an effective radial system. Please note that all of the stated gains and impedances are ground quality dependent, when dealing with verticals nothing is absolute - too many variables are at work.

By following a few simple guidelines, you can obtain excellent performance from vertical antennas mounted on the ground or elevated above the ground. There are a number of verticals available that say "no radials required", but they do have "radials", in the form of a shortened, tuned counterpoise system. As you might expect, you pay a price for such a small counterpoise system - less efficiency.

As you will see in the following pages, you can get fairly high efficiency with a relatively modest radial system that will far outperform small counterpoise systems. It should be noted that counterpoise systems are only good for curing near field losses caused by earth, which is a poor conductor of RF, even with good soil. There is nothing you can do about far field losses that reduce the signal strength and low angle radiation, except get to some saltwater. We briefly discuss salt water locations later on in this article.

Ground Mount or Elevate?

Ground Mounting:

Advantages	**Disadvantages**
☑ The radials are non-resonant so one length (.1 wl minimum at lowest frequency) works on all frequencies	☒ Takes 120 radials to equal an elevated vertical with 2 resonant radials (90% efficiency)
☑ Easy to mount	☒ Surrounding objects can reduce signal strength
☑ Easy access	
☑ Lower visual profile	
☑ Sixteen 0.1 wl (wavelength) radials of lowest intended frequency give 65%-70% efficiency	

Elevated Mounting:

Advantages	Disadvantages
☑ >90% efficient with two .25 wl radials	☒ Mounting is generally more involved
☑ Antenna is generally more "in the clear", so surrounding objects don't cause as much attenuation	☒ Requires two .25 wl radials (minimum) for each band of operation (radials interact, so spacing will affect length)
☑ A peaked metal roof will make a very good all-frequency radial system	☒ Visually higher profile
☑ Contrary to conventional wisdom the vertical doesn't have to be elevated very high, 6 inches elevation results in much lower losses, even on 80m— 5 feet is just fine for 80m	☒ Must be mounted high enough so that people or animals will not accidentally make contact with the radials
	☒ Elevating lowers the impedance so radials may need up to a 30 degree downward slope to achieve a reasonable match

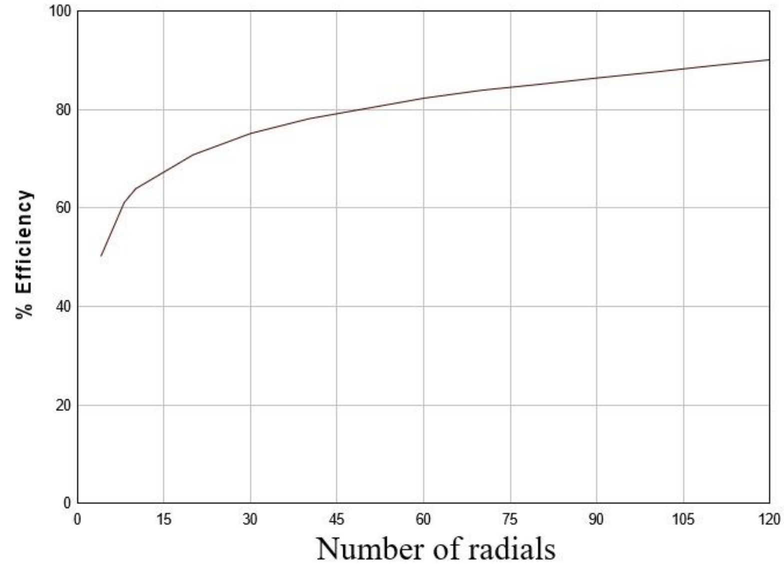
Ground Mounting:

If you choose to ground mount the vertical, pick a spot that will allow you the best chance of spreading your radials evenly around the antenna, and away from trees and other objects if possible. Mount the antenna within one foot of ground if possible, the closer to ground the better. Next, you will need to determine how much effort and wire you are willing to invest in this installation. The tradeoffs are as follows:

1. More radials equals higher efficiency (see Graph 1)
2. Match your radial length to the number of radials using Graph 2, why waste wire
3. If only a few radials can be used (8 or less) do not make them long, it really kills gain
4. Skimping on radials just isn't worth it, EVERTHING is improved with more radials, 25 – 30 is about where diminishing returns begin, the minimum recommended is 16.

Ground Mounting (continued):

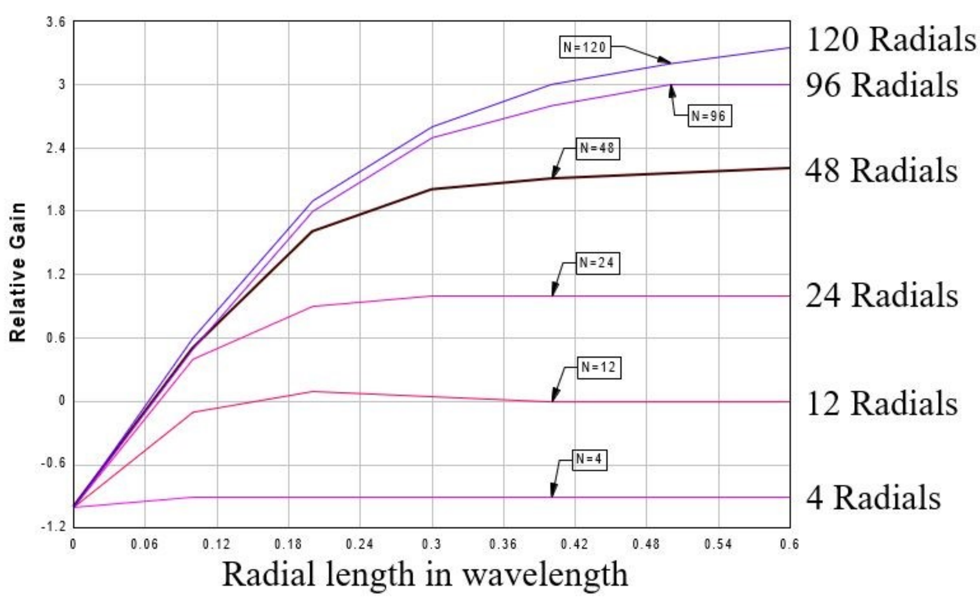
Graph 1



Sixteen radials are what we consider to be the absolute minimum in average soil. A radial system has two main purposes, replace the missing half of the antenna (a vertical is simply a dipole with earth substituting for the missing half when set vertical, unfortunately earth is a very poor RF conductor) and forming an electrostatic shield to prevent much of the RF on the vertical element from capacitively coupling to the lossy soil. The shield requirement is why so many radials are needed in a uniform pattern, exposed earth is a problem!

How much you have to gain with a good radial system depends on how good your earth is. Most of us have poor earth conditions, so the radial system is paramount. The worse the earth is, the more can be gained with additional radials. Graph 2 shows a graph produced by Brian Edward (N2MF) that illustrates the relative signal gain you get with the radials and varying length over poor earth. With better earth, the gain difference between 4 radials and 120 radials will be about 2.5 dB, as opposed to 4 dB with poor earth.

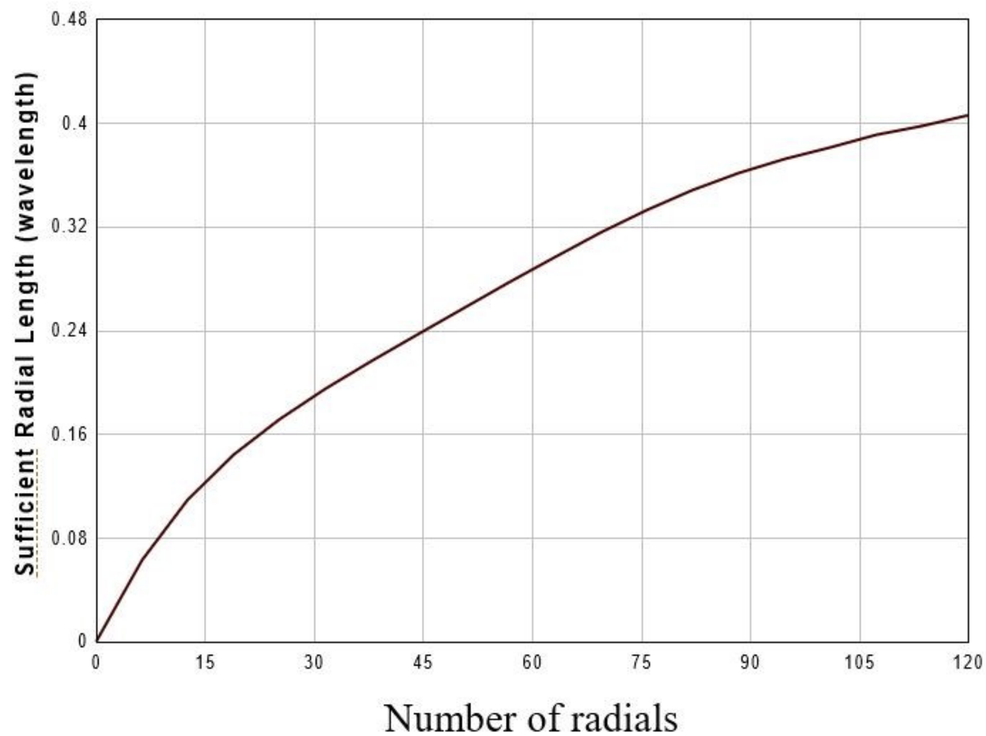
Graph 2



Ground Mounting (continued):

If you are restricted to .1 wavelength radials there is not much advantage to using more than about 24 radials. You can see from Graph 3 that if more radials are used it is very important to make them longer or you are wasting your efforts.

Graph 3



If you cannot lay the radials out in a symmetrical radial pattern, don't worry too much - it will distort your omni-directional pattern slightly but won't reduce the efficiency by much. Lay the radials out in the best manner possible given your situation.

There are various ways to accomplish laying a radial system, including turning corners, etc. Turning a radial back towards the antenna and running it until the obstacle that prevented a radial there is encountered (with about a 10" radius) is a good way to increase the effective shield area. Good results are limited only to your creative energy and determination!

Be aware that very high voltages can exist at the ends of radials, so be certain that no one can come into contact with them. It is a good idea to use insulated wire to protect from corrosion, and don't bury the radials any deeper than necessary, one to two inches maximum. In the manual you will see we suggest mounting the EHU box so the ground stud is no more than 8" - 10" from the radial field. Any straight vertical wire going from the EHU to the radial field adds to the antenna length and causes a mismatch at higher frequencies because it causes off-center feeding. When a good radial field is present verticals work much more efficiently and predictably.

Elevated Mounting:

If you elevate radials even a few inches off the ground the capacitive losses go down dramatically. On 80m, 5 feet is all you need to get a drastic reduction in losses, thus allowing the use of fewer radials. Once the antenna is elevated it is much easier to get reasonable performance with even one .25 wl radial! With one radial the antenna is no longer omnidirectional, the side with no radial is down by 4 dB, that energy now appears at high elevation angles on the radial side and can be advantageous for close in contacts (0 to 400 miles).

Once you elevate a vertical, two .25 wl radials work very well. It is important that you try to keep a 180° angle between the two (opposed, directly in line) for the best pattern. You will need two .25 wl radials for each band you intend to use. Spread the radials out as far as possible to reduce interaction, if they are less than a foot apart it can be difficult to get a good match on all bands.

In Rudy Severns articles he is a big proponent of at least four up to 12 elevated radials, because the antenna becomes much less affected by nearby objects and the gain is better. His contention is that it is actually easier to just cut 25 to 30 30ft radials, it is then easier to deal with radials all the same length without the need to cut them to different lengths and then have to arrange the pairs 180° from each other. The downside is this is 665ft more wire than a 2 elevated radials per band system suitable for 40-6M. The two elevated radials are just slightly down in gain. This system will now work well at any frequency from 40m—6m, for 80m double the length of the radials.

Graph 4

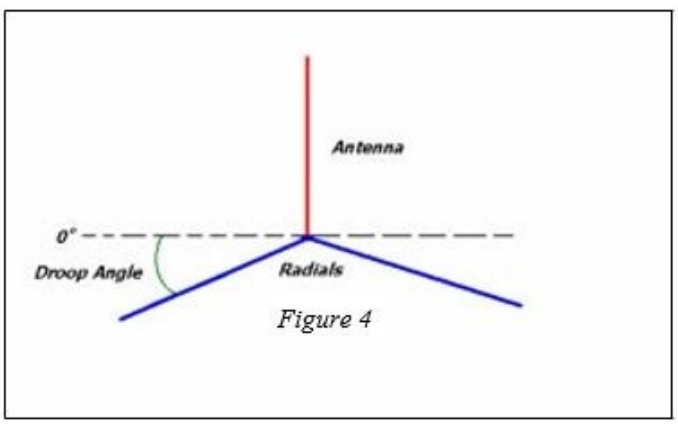


Figure 4

Radial Droop Angle	=	Antenna Impedance
0°	=	22 Ohms
10°	=	28 ohms
20°	=	35 ohms
30°	=	47 ohms
40°	=	53 ohms
50°	=	55 ohms

Note: above 50° results in diminishing returns

Elevated Mounting (continued):

As more radials are added the impedance of the antenna drops, over perfect ground a vertical is 36 ohms. If you put up a vertical with a poor radial system you usually get a good match because the ground LOSS adds to the 36 ohms to get you at or near 50 ohms, but with a big drop in signal strength. To raise this low impedance closer to the desired 50 ohms you can angle the radials downward, this raises the impedance of the antenna as you increase the angle downward. Graph 4 shows the approximate relationship of radial angle to impedance.

Can't get enough droop angle to achieve a good match? Simply adjust the antenna element slightly longer than the factory 1/4 wavelength (up to 20% longer) settings and the impedance will rise. This will cause the radials to be too long, so they may need to be pruned a bit.

Be aware that increasing the antenna 2% to 3% longer may require radials to be 5% to 7% shorter. Once you have a good match, replace the factory default values by saving the new antenna (to do this you will use the "create, modify" feature in the setup mode).

Using a Vertical in Salt Water Situations:

If you are lucky enough to have a dock over salt water, a vertical can offer unparalleled performance for low angle DX. Simply mount the vertical to the dock and attach two radials for band of operation. They can be stapled right to the dock if it is non-metallic. Mounting the vertical in ground flooded by salt water a couple of times per day can be equally effective. Proximity to the ocean improves the far field loss of a vertical and allows very low angle radiation - get as close to the water as possible to enhance performance.

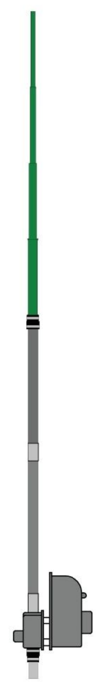
Due to the fact that RF does not penetrate more than 2 inches into the water, direct coupling (a wire in the water) is difficult. Objects like metal floats or boats, providing they are large enough, can make good grounds in salt water. If you are using a metal boat or large metal object, corrosion is no longer a problem because the large surface capacitively couples to the water. When using a small metal float (3 ft x 3 ft is just enough to "connect" to salt water), you want to be certain that the metal does not corrode over time. For long term immersion, Monel is a good (but fairly expensive)

VERTICAL ANTENNAS BIG & SMALL IR

There are two models – the BigIR stands 32 feet in height and covers 40m-6m continuously. There is a stepper motor controlled loading coil available for the BigIR that extends coverage to 80m. Note that when the coil is activated the maximum power rating is 1500 watts. For the SmallIR, there are two coil options; an 80/40/30 option that is rated to 500 watts when activated or a 40/30 option that is rated to 1500 watts when the coils are activated. On either the BigIR or the SmallIR, when the coils are not activated the power rating reverts back to 3000 watts. Radial systems are necessary with all ¼ wave verticals, check our website for our custom made radial options. We also recommend a 1:1 balun for all vertical installations to keep RF from coming back to the shack – these are also available on our website. Fun Fact: the BigIR has a ¾ wave vertical option (at the click of a button) on 21mHz – 54 mHz.

Big IR / Small IR Specs

Specifications	BigIR 40-6 Vertical	Small IR 20-6 Vertical
Weight	15 lb / 6.8 kg	12 lb / 5.4 kg
Wind Load	1.9 sq ft / 0.17 sq m	1.0 sq ft / 0.9 sq m
Longest Element	33 ft / 10.05 m	18 ft / 5.49 m
Optional Coil	Yes - 80 m	Yes - 40 m or 80/40 m
Power Rating	3kW (1.5kW w/80 m coil)	3kW (500W w/80 m coil)
Guyed Wind Rating	100 mph / 160 km/h	100 mph / 160 km/h
Frequency Coverage	6.8 - 54 mHz	13.8 - 54 mHz
Cable Requirements	4 conductor (8 with coil)	4 conductor (8 with coil)
Tuning Rate	1.33 ft sec / 0.4 m sec	1.33 ft sec / 0.4 m sec
Un-guyed Wind Rating	50 mph / 80 km/h	100 mph / 160 km/h
Guyed Wind Rating	80 mph / 133 km/h	



Big IR

Small IR