# The Quadrifilar Helix as a 2 Meter Base Station Antenna

*Here's an easy to build VHF base-station antenna that works equally well toward the horizon or overhead.*

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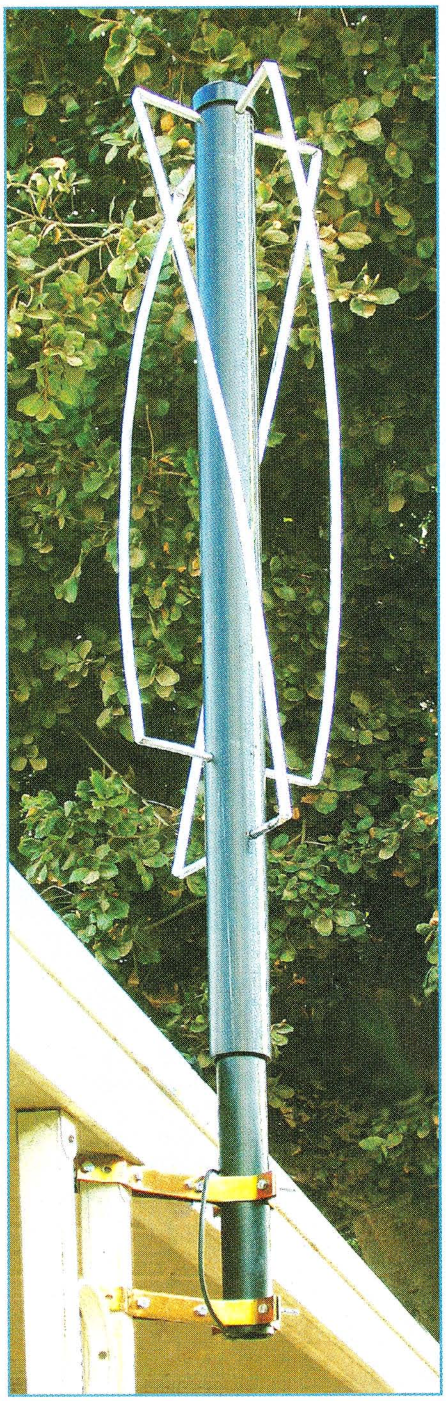
Designed for spacecraft use in the early days of space exploration, the quadrifilar helix (QFH) antenna has not gained much popularity on the ham bands. Yet, as a general-purpose base-station antenna, here for 2 meters, it's hard to beat. It's almost an omnidirectional antenna in both planes, like the mythical *isotropic* radiator. No matter what direction signals come from, or whether the polarization is vertical or horizontal, the QFH works them. It's good for overhead satellites, such as the International Space Station, for horizontally polarized 2 meter SSB simplex stations on the horizon and also for vertically polarized mobile and repeater stations. No, it isn't a gain antenna — no true omni can be. The joy of a QFH is it always gets out.

The QFH is often used by hams for receiving weather satellite pictures from the 137 MHz NOAA automatic picture transmitting (APT) satellites in low polar orbit. Its omnidirectional and circular polarization characteristics accommodate the constantly changing direction and polarization of the APT satellite signals. I have built several for this service. Three of these weather birds still fly by every day — NOAA 15, 17, 18 and 19. (Pictures available at **w6nbc.com**.)

My primary objective here, though, is to tame the QFH as a 2 meter base station antenna, using local hardware store materials and easy construction methods. I also will dispel some of the antenna's technical mysteries. Many existing published QFH articles feature difficult to build designs or too much unnecessary technical jargon.

## Picturing the QFH

Take two vertical full wavelength rectangular loops with open feed points *at the top*. Now place them on the same vertical axis, but with one loop rotated 90° horizontally (quadrature). Also, you need to make one loop slightly larger than the other. This creates a phase shift at the feed point to compensate for the physical rotation of the loops. Next, twist both loops horizontally a quarter turn into helices. Finally connect the feed points in parallel. Voilà — you have a quadrifilar helix antenna.



The curious egg-beater-like configuration of the QFH has useful characteristics — an almost perfectly spherical radiation pattern as well as circular polarization throughout the pattern. This version is right-handed. For left, twist the loops in the opposite direction. For our general purpose 2 meter base station antenna, the twist direction does not matter. And yes, there is a small loss working linear polarized signals (vertical or horizontal) with a circularly polarized antenna, but it is quite acceptable. Commercial broadcast antennas often use this very technique to accommodate both mobile (vertical) as well as home antennas (horizontal).

Next question: Is the QFH a critical design? After building several, I've decided that it's not. The published articles made me initially think otherwise. But after experimenting ham style with square loops and tall versus thin rectangular ones, and the small size difference between the two loops as well as the amount of twist, I have concluded that the QFH is a dimensionally tolerant design. The performance changed little with all these variations. I'll say more about modification concepts later, but for now let's just build a QFH. That's the tricky part for most hams.

## Building a QFH

Obtain a 4 foot length of common inexpensive 2 inch ID schedule 40 ABS pipe, the black pipe used for drains, and 16 feet of ⅜ inch soft aluminum tubing. Drill four pairs of $^{13}/_{32}$ inch holes through the ABS pipe, opposite each other horizontally, for the ⅜ inch aluminum tubing as shown in Figure 1. Carefully note that the vertical distance between the top and bottom hole pairs must be ½ inch less than the actual length measured along the helix of the loops as given in Figure 1.

Drill the top hole pairs 1 inch below the top end of the ABS pipe. This is to allow for an ABS pipe cap. Also, always keep in mind that the bottom of each loop is rotated a quarter turn compared to the top, to form the helix.

Take care to position these holes accurately. The easiest way is to wrap a sheet of paper snugly around the ABS pipe, keeping the edges square. Mark the circumference on the paper and then fold the paper circumference in quarters. You now have an accurate drilling guide. Use a center punch or scratch awl to transfer the hole positions to the ABS pipe.

Next mark the ⅜ inch aluminum tubing with the dimensions given in Figure 1. Cut the two sections to length with a tubing cutter. There is no need to compensate for the bends; this has been accounted for in the dimensions given. Next insert one of the yet-unbent lengths of aluminum tubing through the appropriate opposing bottom holes in the ABS pipe, centering the aluminum tubing in the bottom (8 inch) segment.

For the corners bends, these are most easily made by first flattening the tubing at the bend points. Pipe elbows, as specified for some QFH designs, are difficult to implement. To flatten the tubing, simply adjust the jaws of a pair of clamping pliers to gently make the flat spots. Do so directly over the marks, but only for one bend at a time, right while you are assembling the antenna. The biggest advantage of this method is that it eliminates separate loop segments, any need to solder (difficult with aluminum) and having to make adjustments in loop circumference for the bends.

Make your first bend upward at the bottom of only one loop. Now, on the same side, but this time at the top, again flatten and bend the tubing. Think carefully about the direction the tubing must bend to enter the top hole. This bend will be roughly 90° from the bottom bend. Then, after inserting the loop end into the ABS pipe, gently form that side of the loop into a smooth quarter-turn helix. It should end up with 90° bends top and bottom. The aluminum tubing will easily bend in your fingers.

Next form the other half of the loop, following the same procedure, beginning again at the bottom. Once again, before flattening and bending, consider the direction the aluminum tubing must bend. Also, keep the distance between the vertical sides of the loop roughly constant (8 inches), top to bottom. Again, form this half of the loop into a smooth helix and then repeat the procedure for the second loop.

Lastly, drill four $\frac{5}{32}$ inch holes vertically through the ends of the loops, roughly ⅜ inch from the end of the tubing, at the connection end. Remember: The feed point is at the top of the antenna. Do this with the loops installed on the ABS pipe. These holes will accept #12 × ¾ inch stainless steel sheet metal screws for connection to the feed coax. Screw them in temporarily at this time to form threads and to hold the loops in place.

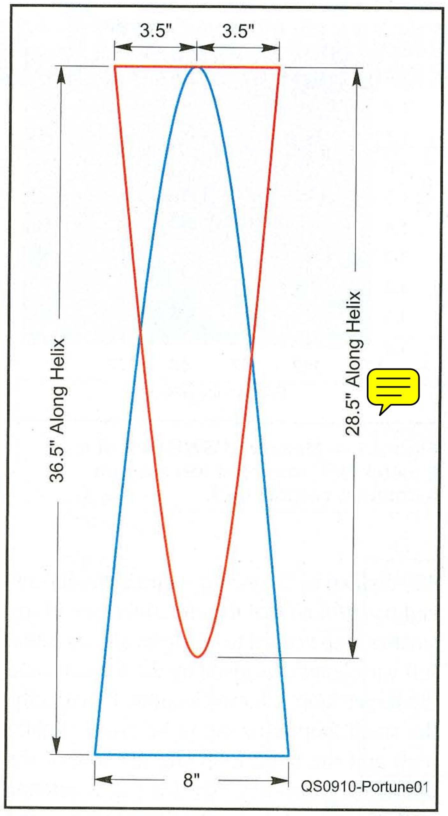



**Figure 1 — Loop dimensions. Note the vertical distance between top and bottom holes is ½ inch less than the length along the helix.**

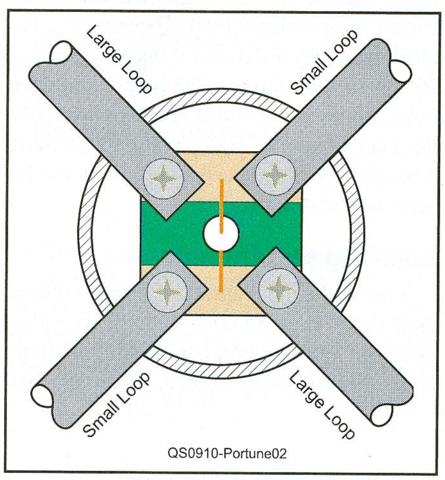



**Figure 2 — Electrical connection to the loops. Observe the phase of the connection.**

## The Feed-Point Connection

The simplest way to connect the loops in parallel to the coax at the feed point is to fabricate the small 1⅜ × 1⅜ inch printed circuit board shown diagrammatically in Figure 2. Its exact dimensions and hole positions are not critical. But be sure to remove the copper foil from the center third. This little PCB provides mechanical rigidity as well as solder points for the feed coax. Carefully note the orientation of the copper-foil strips and the loops.

It is essential to use a balun with a QFH. Without a balun, the common mode coax current will compromise the unique radiation pattern of the QFH. The easiest type is a choke balun simply made up of several turns of the feed coax wrapped around a ¾ inch PVC pipe coupling. It is located inside the ABS pipe, just below the feed point. Simply fill the coupling with as many turns as will conveniently fit, securing the turns of coax through holes near the end of the coupling. Leave roughly 6 inches of coax free above the balun for connection to the loops. You do not need to be precise with any of this.

Assemble the balun and prepare the end of the coax for soldering. Pass the coax through the hole in the PC board from the bottom and solder it. I do not bother with weather proofing. If you wish, apply some silicon RTV sealant. With the ABS pipe cap on top, the 137 MHz QFH I've had in service for two years now shows little signs of weathering at the connections.

For final assembly, drop the balun, coax and feed-line assembly into the ABS pipe from the top. Lower the whole assembly until the balun is below the ends of the loops, but the PC board above them. Install the four #12 × ¾ inch stainless sheet metal screws into the holes in the loop ends through holes in the PC board. Pay attention to the orientation of the copper strips on the PCB compared to the loops, Figure 2. There are two possible ways, one right (as shown) and one wrong. The coax passes out through the bottom of the ABS tube. Finally place a 2 inch ABS pipe cap on top. Do not glue it on; you may wish to get back into the connection point later.

I mounted my antenna with a common antenna vent-pipe clamp and a second short piece of 1½ inch ABS pipe. Plastic is preferable to metal. The finished antenna slips down over the smaller pipe, permitting easy installation and removal.

## Modifying the QFH

The existing published articles tend to make one think that the loops of a QFH must be highly precise in dimension, relative size, shape and twist. On spacecraft, where specifications must be accurately known, I suppose these are appropriate. But in my ham experience, and also in APT weather satellite service, I have found that a QFH is just as tolerant to variations as any antenna.

If one makes the loops roughly square, for example, the radiation pattern approaches spherical (in free space). If the loops are taller and thinner, but still a full wavelength in circumference, the antenna will begin to exhibit some horizontal gain, and a proportionate decrease in overhead gain. For ham and APT satellite use, this is actually desirable. One normally wants more gain toward the horizon than upward. How much off-square can QFH loops be? Frankly — almost any reasonable amount. There is no specific proportion. The radiation pattern changes only slowly as the antenna gets taller and thinner.

The only practical limit to tall and thin is feed impedance. It decreases as the loops get thinner, but again only slowly. Conveniently, QFH antennas come naturally close to 50 Ω. Additional matching is rarely required. This 2 meter version exhibits acceptably low SWR over the entire 2 meter ham band as shown in Figure 3.

Similarly, the amount of helical twist can be varied. Most designs specify 180°, a few 90°. Multiple turns are also possible. My experience is that all twist variation work much the same. The degree of circular polarization does change somewhat, but not enough to matter. I chose 90° mainly for ease of construction. Also, I find a half turn QFH more aesthetically pleasing.

## The QFH on Other Bands

A QFH scales as easily to other bands as does a dipole. I was able to predict the change of size from 137 to 146 MHz merely from the frequency ratio. One only needs to make the total circumference proportional to the wavelength of operation.

In practice, the loops for a QFH antenna of this proportion and made of tubing of roughly this size, need to be roughly 5% larger than the classic metric formula — 300 divided by frequency — predicts. By cut-and-try, I found that the circumference of my smaller loop needed to be physically an actual full wavelength, as given by the formula, and the larger loop 1.1 wavelengths. Electrically, the small loop turns out to be tuned slightly high and the large loop slightly low of the operating frequency. My MFJ-259 antenna analyzer shows two nearby SWR minima, one for each loop as shown in Figure 3.

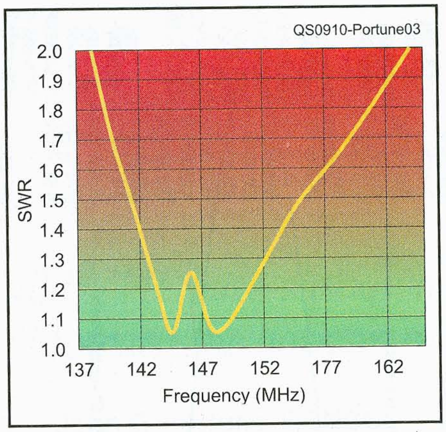



**Figure 3 — Measured SWR plot of my 2 meter QFH mounted low over an aluminum carport roof.**

Actually having two slightly off tuned loops yields an advantage. With one loop electrically high and the other low, the bandwidth of the antenna ends up larger than one would expect from a single loop. Theoretically, the ideal frequency difference is one that causes a 90° phase shift between the loops at the feed point. But as with all other characteristics, one does not need to be highly precise here either. A rough 10% difference in loop size is fine for general ham designs.

## Locating the Antenna

One of the more attractive features discovered in the original design phase for spacecraft use was the comparative insensitivity of a QFH to nearby objects. Many antenna types are worse. As one moves a QFH from free-space toward a ground plane, the pattern does change, but slowly and predictably. It becomes progressively cardioid shaped, with a shallow null downward. The upward pattern remains spherical, and the polarization does not change. This was quite convenient for spacecraft use. It is also good for ham applications. Both my QFH antennas are mounted only a short distance above a flat aluminum car port roof and neither exhibits strange characteristics.

A QFH won't make you the gain king of 2 meters, but as a general purpose base-station antenna it is hard to beat for versatility. For me it was an improvement over the vertically polarized J pole that I previously had in the same location, especially for horizontally polarized 2 meter SSB stations. It is much the same for vertically polarized FM mobiles and repeaters. But with the QFH, I am now also prepared to talk to the ISS overhead without losing the signal, as I would have with the J pole.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*John is active on many bands and modes, predominantly from his HF RV mobile station. He has written a number of articles in* QST, Ham Radio *and* Popular Electronics *magazines and remains active as a VE team leader, ham license teacher and Web site designer. You can reach John at 1095 W McCoy Ln #99, Santa Maria, CA 93455, or at* **jportune@aol.com**. QST