# The "No-Excuses" 160 Meter Vertical

*Stop procrastinating. Build this fun antenna and get on the topband train.*

**John Miller, K6MM**

"My lot size is too small". "I suffer from CCR-itis". "I can't compete with the Big Guns". "I don't have the time. Too complicated". "Too expensive". Sound familiar? It's easy to become a Topband curmudgeon – avoiding putting up a 160 meter antenna because it may be more work than fun. Well, if you're having a difficult time putting a decent signal on 160 meters, here's a possible solution to get you up and running on the "Gentleman's Band", while leaving all those "excuses" behind.

## Background

My first exposure to a Helically Wound Vertical (HWV) was Gary Ellingson's 1972 QST article for a 75 meter antenna.[1] His unique "no loading coil" approach eliminated the need for guying and produced more equal voltage and distribution resulting in a better radiation pattern. I first tried this antenna design while living in Pennsylvania years ago with reasonable results for local QSOs using low power.

For many years, I dropped the HWV approach in favor of dipoles or inverted-Vs for 80/75 meters, but became interested again when reading about Jack Swinden's (W5JCK) clever "broomstick with a Top Hat" portable antenna design.[2] He used ½ wavelength of wire for a targeted resonance frequency of 3.800 MHz and emphasized the importance of carefully calculating and measuring the # of turns around the antenna. Jack's meticulous attention to construction detail was inspiring, and this became my second homebrew HWV project. My FT-847 at 100 watts with this portable little antenna was a fun combination for field day and short trips. There's always something satisfying about a homebrew antenna that generates memorable QSOs.

## Overcoming My Excuses

I'm an avid contester, but had no antenna for 160 meters. In fact, I was a bit cynical about ever being able to put up an effective 160 meter antenna from my rather small California city lot. My NCCC contesting buddies, however, convinced me that I was missing out on some big time fun with the ARRL 160 Meter, CQ 160 Meter, and Stew Perry Topband Challenge contests. No more excuses. It was time for me to get on the Topband Train too.

A review of the literature on 160 meter antenna designs leads to the usual discussion of dipoles, inverted-L's, T's, V's, loops, deltas, and verticals. After thinking about my own QTH constraints I found myself revisiting the HWV option and settled upon a design often discussed but not often deployed in the US: a helically wound vertical antenna using PVC tubing.

An early version of this type of HWV antenna for 160 meters was the "rubber duckie" antenna developed by Joe Moraski, KY3F, in the early 1990s. This antenna was constructed using two 10 foot sections of 4 inch PVC pipe joined, two lengths of 140 feet of #18 wire, and wound at 1 turn per inch over each 10 foot section and the wires connected at the center joint. Then a "top hat" of 1/2 inch mesh dry wall screen one foot in diameter and four feet long was added at the top of the antenna.[3]

However it appears that most HWV antennas for 160 meters have been homebrewed in the UK, where the limitations of "small gardens" are common. In 1980, Frank Lee, G3YCC (SK) described his wire-wrapped fiberglass antenna for 160 meters[4], based on an original design by Alan Wells, G4ERZ[5]. More recently, Phil Sidwell, M0VEY, describes his Topband homebrew helical, including a fairly elaborate earth ground system.[6] This type of antenna appears to have gained widespread popularity throughout the UK and Europe.

## Wire Wisdom

There is no hard-and-fast formula for determining the amount of wire needed to establish resonance in a helical antenna. The relationship between the length of wire needed for resonance and a full quarter wave at the desired frequency depends on several factors. Some of these are wire size, diameter of the turns, and the dielectric properties of the form material. Experience has indicated that a section of wire approximately one half wavelength long, wound on an insulating form with a linear pitch (equal spacing between turns) will come close to yielding a resonant quarter wavelength. Therefore, an antenna for use on 160 meters would require approximately 260 feet of wire, when spirally wound on a support.[7]

Add other possible challenges like narrow bandwidth, poor feedpoint impedance, radiation resistance, efficient top hat capacitance, mechanical constraints, sufficient ground radial system – and you could easily become a Topband curmudgeon. But then you'd miss out on building this fun antenna – which really works!

To try and get a first approximation on a final HWV design, I used modeling software developed by Reg Edwards, G4FGQ.[8] His program models and predicts the performance of a helically wound vertical antenna, mounted immediately above a ground plane, top-capacitance-loaded with a vertical rod or whip. Enter these variables: height/diameter of the helical coil + # turns & diameter of wire + length/diameter of end-loading rod, and you get back theoretically useful data: ¼ wave resonance frequency, length of wire needed, helix wire pitch, capacitance/inductance data, feed-point impedance and expected bandwidth.

## Version 1.0 – A Learning Experience

Based on the success of several UK designs, and to test G4FGQ's software, I decided to put together my first 160 meter HWV. I wrapped 20 feet of 1.5 inch diameter PVC tubing with ½ wavelength of #22 stranded wire spaced 0.25 inch apart, and used a 6 foot vertical rod for top capacitance. In short, this proved to be an unacceptable solution: high resonant frequency, very small bandwidth, low feed point resistance, poor radiating efficiency, insufficient mechanical strength, and overall poor performance. But this first version gave me a chance to really think through the construction variables more carefully, and after discussions with other Topband buffs, a better overall design emerged.[9]

## Version 2.0 – Looking Better

The remainder of this article describes the construction and performance of a very simple but effective HWV antenna for 160 meters. In a nutshell: The antenna is made by telescoping three 10 foot PVC sections together, helically winding it with ½ wavelength of antenna wire, attaching a capacitance hat to the top, and feeding it with a 50-ohm feed line against 8 ground radials. The entire construction can be easily completed in just one day using very simple tools.

## Construction

**Step 1. PVC Painting**

The antenna is made from three 10 foot sections of readily available PVC tubing in three diameter sizes: Top Section = 1 inch, Middle Section = 1½ inches, and Bottom Section = 2 inches. To make this antenna environmentally & stealth friendly, the three PVC sections were spray-painted green by suspending each 10 foot section from two pieces of nylon rope between two branches of a convenient backyard tree. Brown paint would work just as well. Figures 1 and 2 show a PVC section before and after painting. All three 10 foot sections were allowed to thoroughly dry before proceeding (see Figure 3).

Figure 1. PVC Before

Figure 2. PVC After

Figure 3. Painted PVC Pipes

**Step 2. Bottom Section: Coax, Antenna and Ground Connections**

The bottom 2 inch PVC section is prepared for both ground and coax connections by drilling the necessary mounting holes. A PVC cap is placed on the bottom of the 2 inch diameter PVC tube, and then, using a felt-tip marker, a circle is drawn around the PVC just above the border between the bottom cap and PVC section. This "marker" ensures that subsequent drilled holes will clear the bottom PVC cap.

Coax Connection: The PVC cap is then removed, and then holes are drilled for the SO-239 connector and 4 attachment screws. The SO-239 hole is centered about 2½ inches above the marker (see Figure 4).

Bottom Antenna Binding Post: One 1/8 inch hole is drilled for the antenna binding post, placed 2 inches above the marker. A red binding post was used for the antenna connection.

Ground Binding Posts:  Two 1/8 inch holes are drilled for the ground posts, each placed 1½ inches above the marker.  Black binding posts were used for ground connections.

Summary: The 3 binding post holes (i.e., 1 antenna + 2 ground) are placed equidistant from each other around the PVC section.  The antenna post and ground posts are staggered by about ½ inch to avoid any possibility of shorting (see Figure 5).

Figure 4.  SO-239 Connector

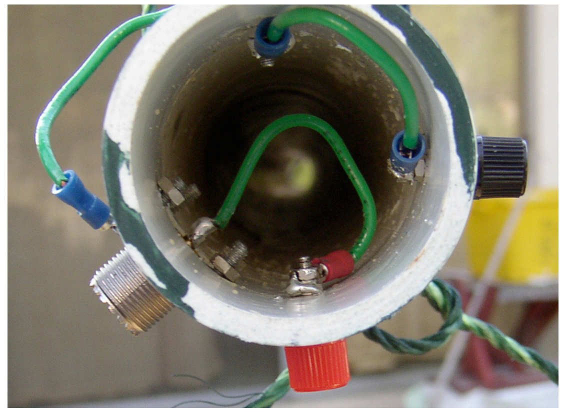


Figure 5.  Binding Posts & Internal Wiring

**Step 3.  Wiring:  Coax Connector and Antenna Post**

One end of a 4 inch piece of #14 wire is soldered to the center connector of the SO-239.  The other end is then soldered to either a spade or ring lug.  The wire is then pushed through the prepared SO-239 hole in the 2 inch PVC tube, and the SO-239 connector secured to the PVC tube using only 3 of the 4 mounting holes.  The free end of the insulated wire is connected to the inner section of the red antenna post using the spade or ring lug.  After securing the antenna post a binding nut, the connection can be soldered (see Figure 5).

**Step 4.  Wiring:  Coax Connector and Ground Post**

A 6 inch section of #14 insulated wire is soldered (or crimped) to spade lugs on both ends.  One end is connected on the outside of the PVC to the remaining SO-239 screw and secured to the PVC.  The other end of the #14 wire is connected to the closest black ground binding post on the outside of the PVC.

Inside the PVC, another piece of #14 wire is attached between the 2 ground binding posts.  This essentially connects both ground binding posts and the coax base together.  Check to be sure the antenna and ground connections inside the PVC are clean and not touching each other.  Braided coax, such as RG-58, can also be used instead of the #14 wire for ground post connections.  At this point, the SO-239 and all binding posts should be tightened and secured.  For extra strength and protection, the binding posts can also be glued to the PVC, both inside and outside (see Figure 5)

**Step 5.  PVC Mast Preparation and Assembly**

The Top, Middle, and Bottom sections are assembled using a high-tech solution: duct tape.  I actually used Gorilla Tape[10] for wrapping because it uses two layers of adhesive and two layers of fabric backing to make it much stronger than standard duct tape.

First, the 1 inch diameter PVC tubing is shortened from 10 feet to 7 feet 6 inches by cutting off 2 feet 6 inches from one end.  Duct tape is then wrapped around the tubes as follows:

For the Top Section (1 inch diameter tube) = Two wrappings.  First wrap = 2 inches from bottom of tube.  Second wrap = from 9½ to 11½ inches from the bottom of the tube (see Figure 6).

For the Middle Section (1 ½ in diameter tube) = Two wrappings.  First wrap = 2 inches from bottom of tube.  Second wrap = from 22 to 24 inches from the bottom of the tube (see Figure 6).

Figure 6.  Wrapped With Duct Tape

Figure 7.  Telescoped

The 3 PVC sections are then telescoped together.  When assembled, the Middle Section will extend 24 inches into the Bottom Section, and the Top Section will extend 11½ inches into the Middle Section.  It's important to use enough duct tape to ensure a good fit between the PVC sections (see Figures 7 and 8).

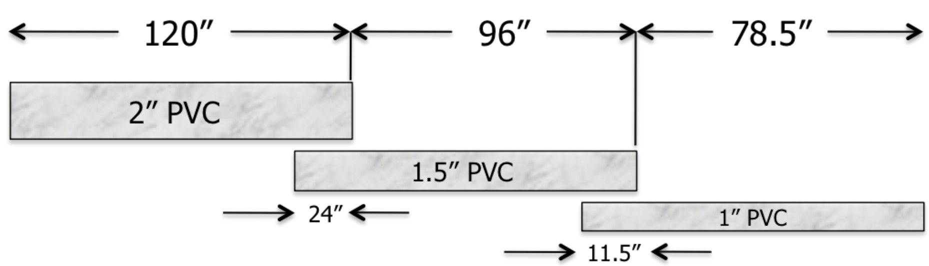



Figure 8.  PVC Sections - Overlap

The next step in PVC assembly is to further secure the "joints" with a bolt and nut.  The lower joint (between the Middle and Bottom sections) is secured by drilling a ¼ inch hole through both PVC sections about 12 inches from the top of the 2 inch diameter Top PVC section, and using a 3¼ inch bolt, nut, and washer to fasten the sections together.

The middle joint (between the Middle and Top sections) is secured by drilling a similar hole, about 6 inches down from the top of the 1½ inch diameter Middle PVC section, and using a 2¾ inch bolt, nut, and washer to secure the joint.

Top Antenna Binding Post:  Similar to the Bottom antenna post previously mentioned, a Top antenna post is prepared by drilling a 1/8 inch hole one inch from the top of the Top PVC section.  A red-capped binding post is attached to it, using a nut and glued to secure it.  The helically wound antenna wire will be connected to this post, which will also be the antenna-to-capacitance hat attachment point (see Figure 7).

**<u>Step 6.  Helically Winding The PVC</u>**

With the sections assembled and fortified, the antenna is ready to be helically wrapped with wire.  As previously mentioned, experimentation with HWVs has shown that a half wavelength of wire is often needed for quarter wave resonance, assuming the turns are evenly spaced.  At a desired resonance frequency of 1.825 MHz, 256 feet 5 inches of wire is required for a 160 meter vertical, using the formula 468/freq.  For this first version of the antenna, I chose #22 insulated wire for the antenna – I had a good supply sitting in the garage.

Using our kitchen table, which measures 5 feet long and a coffee can with 2 large screws protruding from sides at the top and bottom 180 deg apart (to keep the wire from falling off the can as it was being wound), my XYL "unwound" the wire from the supply spool, while I wound it onto the coffee can.  50 times across the kitchen table = 250 feet + an additional 6 feet 5 inches did it.  The wire was cut, adding a few extra inches for experimentation, but keeping the 256 feet 5 inch point marked.

Figure 9.  Wire Wrapping

Wrapping begins by first attaching the antenna wire to the Bottom Antenna Binding Post of the 2 inch PVC section using a spade or ring solder lug. The wire is then wound from bottom to top, being careful to keep the "winding pitch" as consistent as possible, and avoiding the bolts near the two PVC joints. A spacing of about ½ inch seemed to work well. Wire wrapping is not a difficult step, but does require a bit of patience. It's best not to rush this part of the project. Duct tape is helpful here every few feet to keep the windings secure (see Figure 9). In a later version of this antenna, I hot-glued the antenna wire to the PVC for even better protection.

The end of the wire at the top of the antenna is then soldered to a spade or ring tongue and attached to the Top Antenna Binding Post with the red cap at the top of the 1" PVC section.

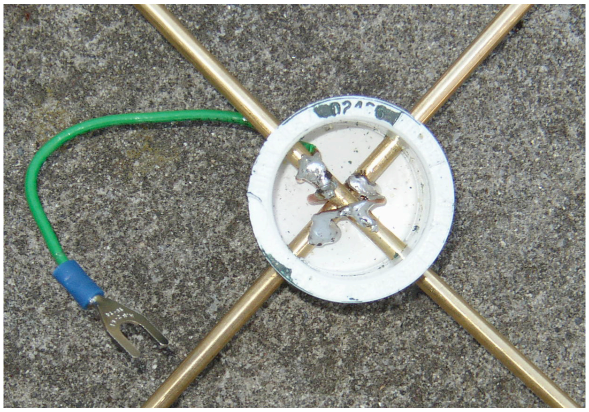
Option For Portability: It's possible to make the antenna portable by cutting the antenna wire at the two PVC joints. Then, after removing wire insulation, alligator or "quick disconnect" clips are attached to the antenna wire ends. The antenna can then be pulled apart, moved, re-telescoped together, and the full antenna wire length restored by simply connecting the antenna clips together.

**Step 7. Top Cap Preparation: Capacitance Hat**

There are several designs for a suitable HWV capacitance hat to provide capacity termination and reduce noise. At first, I chose the "circular hat" design described by Jack Swinden (W5JCK), where six 12 inch brass rods are spaced equally around a PVC cap, and soldered together.[2] However, I eventually settled on a simpler "square hat" design using two 36 inch brass rods spaced 90 degrees apart, and connected together with #14 gauge copper wire.[9] Either of these methods work well. The "square hat" design is described next.

The square hat construction begins by drilling four 1/8 inch hole 90 degrees apart in the 1 inch PVC cap, about 1 inch from the bottom. An additional 1/8 inch hole is drilled next to one of these holes. The brass rods are inserted into the cap, forming an "X". A pair of pliers is helpful here, as it will be a snug fit, which is what you want.

Next, a 6 inch piece of #14 insulated wire is stripped on one end, and soldered to a spade or ring lug on the other end. The stripped end is slipped through the remaining 1/8 inch hole and wrapped securely around the "X" junction of the two brass rods inside the PVC cap, where everything is securely soldered (see Figure 10). The brass rods are tied together externally by connecting them together with #14 gauge bare copper wire in two places: the tips of the rods and also midway between the rod ends the and PVC cap. The bare copper wire is soldered to the brass rod at all 8 intersections, to complete the "square hat" (see Figure 11).



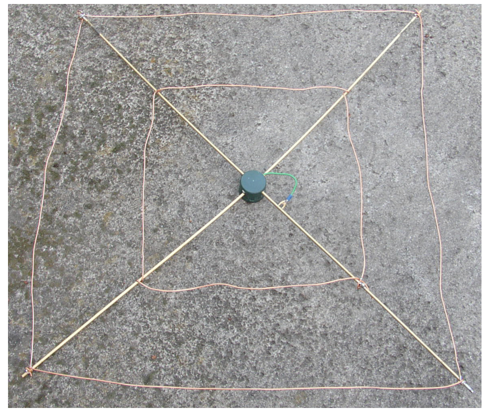


Figure 10. Inside Top PVC Cap Figure 11. Completed Square Hat

Finally, the PVC cap is attached to the Top Section of the antenna, and the capacitance wire secured to the Top Antenna Binding Post using the spade or ring lug. For maximum result, it's important to have a good electrical connection between the antenna wire and capacitance hat.

**Step 9. Bottom Cap Preparation**

The bottom cap is used to support and protect the antenna. A ¼ inch hole was drilled in the center of a piece of scrap plywood (about one foot square). Another ¼ inch hole was drilled in the bottom of the 2 inch PVC cap. The threaded aluminum rod was trimmed to 12 inches, and run through the bottom PVC cap, and then through the plywood (see Figure 12). Nuts and washers were attached on the threaded rod inside the cap and also on the other side of the plywood. When tightened, only 2 inches of rod was left inside the cap, to ensure that the antenna and ground wiring in the bottom section of the mast would not be disturbed (see Step 2). About 10 inches of threaded rod was left sticking out from the bottom of the plywood (see Figure 13). The plywood base serves as a stabilizing platform to ease final installation of the vertical. By gently standing on it and pushing, you can easily drive the 10 inches of threaded rod into the ground.

Figure 12. Bottom Cap on Plywood Figure 13. Showing Threaded Rod

**Step 9. Erecting The Antenna**

After the PVC sections were bolted together, and completely wire wrapped, the capacitance hat was attached to the top of the antenna, including the capacitance wire-to-antenna binding post connection. The antenna is now ready for final installation (see Figure 14). The bottom 2 inch PVC cap/plywood base was set in the ground at its mounting location. Bracing the bottom against the ground, the antenna was carried to the PVC cap/plywood base and carefully set into the PVC cap. One person can carry & mount the antenna but it's a bit easier with two folks (see Figure 15).

Figure 14. Ready To Erect

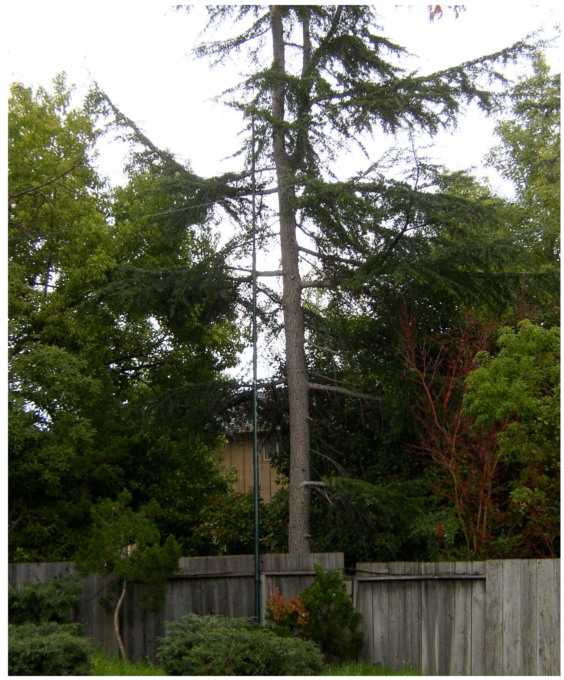


Figure 15. Installed and Neighbor Friendly

My QTH required bracing the mast to my back fence and securing it at the 6 foot point with nylon rope. To keep the vertical, "vertical", a section of nylon rope was also attached at 12 feet using a convenient tree limb and the rope secured at ground level. Final guying/bracing will depend upon your antenna placement.

Radial Wires: This antenna does require some ground radials. Of course, use as many as your QTH allows. I started with four 1/4 wavelength ground radials cut for 160 meters and have expanded that number now to eight, using #16 stranded insulated wire. Spade lugs are soldered to ground radials which are then attached to one of the two ground posts. Because of the geometry of my property, my radials cover only a 180 degree arc but they work pretty well.

Initial Readings: After attaching a 6 foot piece of 50-Ohm coax, an MFJ 249B antenna analyzer showed resonance close to 1.790 MHz. The antenna wire was adjusted at the bottom to bring the resonance closer to 1.830 MHz. Running 500 watts through this antenna without a tuner showed a 50 KHz bandwidth, with <2:1 SWR. With a tuner, the antenna can be adjusted anywhere from 1.800 to 1.900 MHz with an SWR under 2:1.

## Version 3.0 - Update

After a few months of use, I took down the antenna and decided to fortify the antenna wire by hot gluing it to the PVC. While on the ground again, the entire antenna was re-wrapped using 4-conductor #18 wire stranded wire – I had a good supply sitting in the garage. At each end of the antenna the ends of the 4-conductor wire were twisted and soldered together before wrapping and attaching to the Top and Bottom antenna binding posts. I also added two elevated radials around the fence line (see Figures 16 and 17).

Figure 16. Re-wrapped, Hot Glued

Figure 17. Latest Version

Although I have not done any side-by-side comparisons, this updated version of the antenna appears to "hear" better, and feedback on the air tells me that I have a somewhat stronger signal. However it is not necessary to use 4-conductor wire with this antenna. A single conductor works just fine, and is easier to wrap around the PVC tubing.

## On-The-Air

So how does this Helically Wound Vertical for 160 meters perform? From the West coast, it's a solid performer throughout the North America. I have worked all 50 states, Canada, and Mexico during the last year with it, almost all confirmed via LoTW. I was awarded First Place, Single Operator, Low Power for the Santa Clara Valley section in the 2007 ARRL 160 Meter contest. In the 2009 CQWW 160 Meter contest, I worked 46 states and 7 countries using 600 watts in just a few hours of operating. For DX, with limited operating time, I have worked 30 countries. Overall, this antenna plays well to the Far East, South Pacific, Eastern Russia, Caribbean and Central/South America. Europe is the most difficult region to reach from my location, but that's generally true for most West coast stations.

Am I the loudest signal on the band? No. Can I compete in pileups with folks having better antennas or higher power? No. But am I having fun on Topband using a homebrew antenna that generates memorable QSOs. You bet!

There are some obvious improvements that can be made to increase overall on-the-air performance with this type of antenna. They include, among others:

- Installing more ground radials in a full 360 degree pattern

- Using a remote tuner at the antenna feedpoint to reduce coax losses
- Running legal-limit power
- Adding beverage antennas for improved reception

## **Summary**

A Helically Wound Vertical is not "the" perfect antenna for 160 meters, but for a small lot, or where CC&R's are strictly enforced, this easy-to-build vertical is a good alternative to an inverted-L or dipole.  During the last year, I have helped other hams around the country get on the air with this HWV design for 160 meters.[11]

This unsolicited comment from Armand Sun, K6IP, is typical of the feedback I've received:

"I finally put up the HWV antenna and I'm happy to report that it works FB.  Mine has two feed options:  ladder-line or coax.  I'm currently feeding with ladder-line and one elevated radial from leftover wire on the spool and the results are excellent!  It takes a KW from 1.8 - 1.9 MHz.  I painted mine olive drab with black #14 wire so it's pretty stealthy.  I would imagine brown would be good too.  Sometimes the traditional designs just don't blend well with the existing antenna farm.  A Helically Wound Vertical is a good option for small lots or for those with antenna restrictions.  Thanks for the design.  It was fun to build and just what I needed for a Topband solution."[12]

So, no more excuses for Armand -- or Me.  Now how about you?

John Miller, K6MM
Published in QST, June 2009, pages 32-36.

## Notes

[1]G. Ellingson, WA0WHE. "A Helically Wound Vertical Antenna For The 75-Meter Band," *QST*, Jan1972, page 32.

[2]J. Swinden, W5JCK. (a) http://w5jck.com/broomstick_antenna/80m_helical_antenna.html (b) http://www.dxzone.com/cgi-bin/dir/jump2.cgi?ID=19786

[3]J. Moraski, "The Rubber Duckie 160 Meter Antenna", *HF Antenna Book*, published by CQ Magazine, edited by Bill Orr, W6SAI, 1996, p. 615.

[4]F. Lee, G3YCC. "A Practical Antenna for 160 Metres" http://www.zerobeat.net/g3ycc/ant1.htm

[5]A. Wells, G4ERZ. http://topband.blog.cz/0612/a-practical-antenna-for-160m-by-alan-g4erz

[6]P. Sidwell, M0VEY. http://uk.groups.yahoo.com/group/topband-helical/

[7]*The ARRL Antenna Book*, 21st Edition, 2007, p. 6-38.

[8]R.J. Edwards, G4FGQ. (a) "Model and Predict Helically Wound Vertical Antennas". http://www.smeter.net/antennas/helical-modeling.php August 2, 1997; (b) "Very Short, Helically Wound, Monopole Antennas", http://www.smeter.net/antennas/short-helical.php, May 19, 2006

[9]I am especially grateful to Jon Sims, N7ON, for sharing his ideas and experiences with me. J. Sims, N7ON – Personal communications, January 2006.

[10]Gorilla Tape. http://www.gorillaglue.com/tapes.aspx

[11]A downloadable construction manual is posted on my website here: http://k6mm.com/antennas/160M.pdf

[12]A. Sun, K6IP. Email communication, January 29, 2009. Quoted with permission.

## Parts List

Home Depot or Lowe's
10' length, 2" diameter schedule 40 PVC
10' length, 1-1/2" diameter schedule 40 PVC
10' length, 1" diameter schedule 40 PVC
1" diameter PVC end cap
2" diameter PVC end cap
1/4" x 3 1/4" threaded bolt, nut, washer
1/4" x 2 3/4" threaded bolt, nut, washer
1/4" x 1 foot threaded aluminum rod
3 foot length brass rods (2 required)
4 1/4" diameter nuts
4 1/4" diameter washers
Rust-Oleum PVC Spray Paint (dark green or brown)

Radio Shack
2 packets, multipurpose posts
1 packet, crimp-on spade or ring tongues
1 packet, alligator clips

Misc
500 foot roll insulated stranded wire (you can use 14, 16, or 18 gauge)
Roll of your favorite ground wire for radials (insulated or un-insulated)
Duct tape or Gorilla tape (2" wide)
SO-239 chassis mount coax socket + mounting screws/nuts

Tools
Soldering iron, solder, glue/glue gun, hacksaw, drill, 1/8" drill bit, 1/4" drill bit, felt-tip marker

## Biographical Sketch

## John Miller, K6MM

John Miller, K6MM, is the President of the Northern California Contest Club, which sponsors the California QSO Party every October. He was first licensed in 1958 as WV2BQJ in Syracuse, NY. His first station was a Heathkit DX-40 and Hallcrafters SX-99 receiver, with an end-fed long wire. He has also held callsigns in Ohio (WB8CHZ), Pennsylvania (WA3VTM), and California (WA6OMA, KE6MI).

John recently retired after careers in research, marketing, and sales in the pharmaceutical, medical diagnostics, and human resources industry. He holds BS and MS degrees from Syracuse University, an MBA from Pepperdine University and a PhD in chemistry from Case Western Reserve University. John worked his way through college as a keyboard player in a rock and roll band. His hobbies today, in addition to his three grandchildren, include the radiosport of contesting, experimenting with antennas, and exploring the back roads of the Bay Area on his Harley. His personal website is at http://www.k6mm.com. You can reach John at 6349 Slida Drive, San Jose, CA 95129 or at **k6mm@arrl.net.**