

Copper Pipe J-Pole Antennas

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Rory and I have had excellent experience building and using J-Pole antennas constructed from 1/2 inch ridged copper pipe, so we decided that we would share our experiences. A copper pipe J-Pole antenna is a single band antenna that is much like a half wave dipole in that it is relatively easy to build, and when you are done you achieve the satisfaction of having built a very good antenna that works as well as expensive commercial antennas. That is exciting.

My own experience with J-Poles did not start out so well. Thinking that copper pipe would be hard to work with, I built some J-Pole antennas using TV twin lead. TV twin lead J-Poles are commonly known as “roll up” portable antennas since you can roll one up and put it in your luggage when you are on travel. A roll up J-Pole provides a reasonable antenna that you can hang up in your hotel room. While a TV twin lead J-Pole is great for this purpose, I was not very impressed with the antenna for a more permanent installation. I did not have any problem with the physical aspect of the antenna. I simply slipped the twin lead J-Pole inside a piece of PVC pipe and made a very nice looking antenna for 2 meters. I also made 220 MHz and 440 MHz antennas following this approach. The problem that I had was that I was never able to tune them for a low SWR. The best that I was able to do was about 1.75 : 1. In hind sight, I think that the problem may have been that I did not experiment enough with the coax tap positions.

My RV forced me to reconsider J-Pole antennas. My RV has a “rubber” roof so VHF and UHF mag mount antennas will not work on it. To overcome this problem I built three 1/4 wave vertical ground plane antennas, complete with radials, and mounted them on the RV roof. The antennas covered 2 meters, 220, and 440 MHz. The ground plane antennas worked ok, except that the radials bounced on the RV roof as I drove down the road. From inside the RV it sounded like I was in a perpetual rain storm, even on nice sunny days. On top of that, the radials began to break off one by one after a few trips across country. I really needed to do something better.

After many hair brain ideas that didn't work out too well, I reluctantly decided to try a copper pipe J-Pole for 2 meters. It wasn't hard to make. I bought the copper pipe, elbows, and tees at a local plumbing store. I used a hack saw to cut the pipe pieces to length and a K-mart torch to solder the pieces together. It was kind of fun. Then for the big test. The 2 meter antenna worked perfectly on the first try! It has a flat 1 : 1 SWR across the entire 2 meter band. I followed that with a 440 MHz J-Pole. That one worked well also, but was a little harder to tune.

A J-Pole antenna, like the one shown in Figure 1, is an end fed half wavelength antenna with a quarter wave tuning stub (the J part of the antenna) at one end that matches the coax feed line to the half wavelength radiating element. The total length of the antenna is thus 3/4 of a wavelength. The coax is connected to the tuning stub a

short distance up from the based of the stub.

The J-Pole antenna is an adaptation of a 1/2 wavelength radiator end fed by a 1/4 wavelength transmission line that was developed as a trailing HF antenna for Zeppelin airships in the 1930s. Used as a vertical VHF/UHF antenna, the J-Pole has the advantage that it is omnidirectional, has a low angle of radiation, and does not require a ground plane as do 1/4 and 5/8 wavelength verticals.

There are a lot of articles on J-Pole antennas. In what follows, Rory and I describe an approach which we collectively arrived at to build copper pipe J-Pole antennas that are easy to construct, durable, and easy to tune. We also try to take the “magic” out of the J-Pole design by explaining how we arrived at the appropriated lengths for the various sections of the antenna.

Technical Background

The upper section of the antenna, Section A shown in Figure 1, is the antenna’s 1/2 wavelength radiator. The lower section, Section B, is the 1/4 wavelength tuning stub. So how long is a half wavelength? The wavelength for a very thin bare wire antenna in free space (an antenna wire with no insulation) is equal to the speed of light (300 mega-meters per second) divided by the frequency f in MHz of the radio signal to be radiated by the antenna ($f = 146$ MHz for the center of the 2 meter band). To convert the wavelength to inches, multiply the wavelength in meters by 100 to express the length in centimeters, and then divide by 2.54 centimeters per inches. This wavelength number must be multiplied by a factor K , where $K \leq 1$, to account for the fact that the antenna will be constructed from 1/2 inch diameter copper pipe instead of a very thin wire. So wavelength

$$L = K [(300 / f)(100)] / 2.54 \text{ inches} = K (11811 / f) \text{ inches.}$$

The factor K for bare wire (and bare copper pipe) can be determined from the graph show in Figure 2 that was obtained from the ARRL Antenna Book. The numbers along the bottom of the graph are equal to the ratio r of the wavelength for a very thin wire to the diameter d of the wire (or pipe) to be used in building the antenna. That is

$$r = (11811 / f) / d$$

For 1/2 inch copper pipe, $d = 0.625$ and at $f = 146$ MHz, $r = 129$.

Reading vertically from 129 at the bottom of the graph up to the solid line curve and then horizontally to the left hand axis shows that $K = 0.958$, approximately, for 1/2 inch copper pipe at 146 MHz. Doing the same calculation for $f = 440$ MHz arrives at a value of $K = 0.945$. We can simplify our work by using an approximate value for K which is equal to average of the 2 meter and 440 MHz numbers. This approximate value of $K = 0.952$, and is suitable for building 2 meters through 440 MHz antennas. Notice that values of $K < 1$ created by using thicker antenna wire or pipe makes the

antenna shorter than it would otherwise be. Thicker “wire” also broadens the bandwidth of the antenna, which is a good thing.

The above procedure can be used to arrive at the K value for any size bare copper or aluminum pipe (for example 3/4 inch pipe which might be used to make a larger 6 meter J-Pole). If you are making a “roll up” J-Pole antenna out of TV twin lead or ladder line, then you must obtain the value of K (the velocity factor) for that particular type of cable from the manufacture or tables such as found in the ARRL antenna books.

Plugging in the average value for K obtained above in the wavelength equation gives

$$L = 11244 / f \text{ in inches}$$

for 1/2 inch copper pipe J-Pole antennas. We will use this wavelength equation for all of our calculations.

For a 2 meter $f = 146$ MHz J-Pole antenna, the 1/2 wavelength radiating section (Section A) is equal to

$$A = 0.5 L = 0.5 (11244 / 146) = 38.5 \text{ inches}$$

and the 1/4 wavelength stub section (Section B) is equal to

$$B = 0.25 L = 0.25 (11244 / 146) = 19.25 \text{ inches.}$$

The length of the spacing Section S between the two 1/4 wavelength stub elements is not too critical. The primary consideration is to use a spacing that makes the antenna easy to build. Since the stub is actually a 1/4 wavelength transmission line, changing the spacing changes the stub’s characteristic impedance and thus the tap point D at which the coax feed line is attached. The characteristic impedance Z of the stub is equal to

$$Z = 276 \log (2S / d)$$

where S is the spacing between the elements and d is the diameter of the copper pipes.

The impedance at the bottom of the stub is approximately 0 ohms (the stub is short circuited at the bottom) and very high at the top end where it is an open circuit. In the middle the stub is equal to its characteristic impedance which is on the order of 225 ohms. Somewhere between the bottom of the stub and the middle, the impedance will be roughly equal to 50 ohms. The tuning process consists of moving the coax tap point up and down the lower part of the stub until the 50 ohm position is found represented by a minimum SWR reading.

Reasonable values for S

BAND	S
2 meters:	2.5 inches
	1.75 inches
440 MHz:	1.25 inches.

Building VHF and UHF J-Pole Antennas

The following table summarizes the dimensions (in inches) for 1/2 inch copper pipe J-Pole antennas designed for the center of the 2 meter, 223 MHz, and 440 MHz amateur radio bands.

Band	1/2 L Radiator (A)	1/4 L Stub (B)	Spacer (S)	Tap Point (D) Approximate
146.0 MHz	38.5	19.25	2.50	4.0
223.5 MHz	25.2	12.6	1.75	2.5
440.0 MHz	12.8	6.4	1.25	1.25

To build an antenna, begin by cutting a section of copper pipe to length A (see Table). Cut two pieces of pipe to length B, and cut one piece to length S. Also cut a Section M to any desired length. Section M is for mounting the antenna to a mast. Generally about one to two feet long is a good length for Section M. Assemble Section M and the stub part of the antenna, including the in-line coupler on the top of the inside stub element (the one inserted into the T), as shown in Figure 1. Do not install Section A. Solder all of the joints. Push the lower end of the Section A pipe into the in-line coupler at the top of the stub and temporarily secure it with a hose clamp. Place and end cap on the top end of the Section A pipe, but do not solder it to the pipe yet.

Next cut a section of RG-8X coax to about 2 to 4 feet in length. Solder a PL-259 connector on the bottom of the coax in the usual manner. Solder a second PL-259 connector at the top of the coax, but leave the outer shell off this connector. Cut two pieces of #12 solid wire to a length of about 6 inches. Solder one to the center pin of the upper PL-259 connector. Solder the second one to the outer part of the connector as shown in Figure 3. Using a hose clamp, clamp the center conductor wire to the D tap point on the inside stub element (the one soldered into the T). Hose clamp the other wire to the D tap point on the outside stub element.

To test the antenna, connect it through an SWR meter to your VHF/UHF radio and

tune the radio to the center frequency of the band. By loosening and repositioning the tap point hose clamps and wires, move the coax tap point up and down the lower part of the stub until the lowest SWR reading is obtained. If the lowest SWR is not 1 : 1, then tune the radio up and down in frequency to locate the 1 : 1 SWR point. If this frequency is lower than the band center frequency, then the Section A element is too long. Remove it from the top of the stub and cut a small amount off, about 1/4 inch. Reinsert Section A into the top of the stub, reconnecting the hose clamp. This should move the SWR 1 : 1 point up in frequency. Continue doing this until the 1 : 1 point reaches the band center frequency. If the 1 : 1 point is above the band's center frequency, then Section A is too short. If this is the case you will have to cut a new longer Section A piece. When that is done, hose clamp it into the coupler at the top of the stub and proceed as above to adjust the antenna to the band's center frequency. Once the antenna is tuned, check its bandwidth. The antenna should cover the entire band with an SWR of less than 1.5 : 1. If it does not, you may have to shift the antenna center frequency (the 1 : 1 SWR frequency) so that you get a 1.5 : 1 or less SWR across the section of the band that you are most interested in.

Once the antenna is tuned, remove the hose clamps and solder the coax wires to the final D tap points. Cut off any excess wire. Test the antenna again to insure that it has remained tuned. Next remove the hose clamp and solder Section A into the coupler at the top of the stub. Also, solder the end cap on the top of Section A. Finally, use two UV Tie Wraps, installed in a crossing configuration, to secure the coax to Section S. The Tie Wraps act as a strain relief minimizing stress on the two coax feed line tap points.

The final step in building the antenna is to protect it against the elements. Apply 30 year silicon sealant, it comes in a tube that you can buy for \$3 at Home Depot, to the end of the upper coax connector to keep water out of it. Next sand the entire antenna using fine grain sand paper. Then use rubbing alcohol to clean the antenna. Finally, paint the antenna with gray gloss primer paint. The paint will protect the copper pipe from corroding. The gray color causes the antenna to blend into the sky so that it is not as noticeable when installed.

This completes the antenna. It should provide you with many years of excellent service.

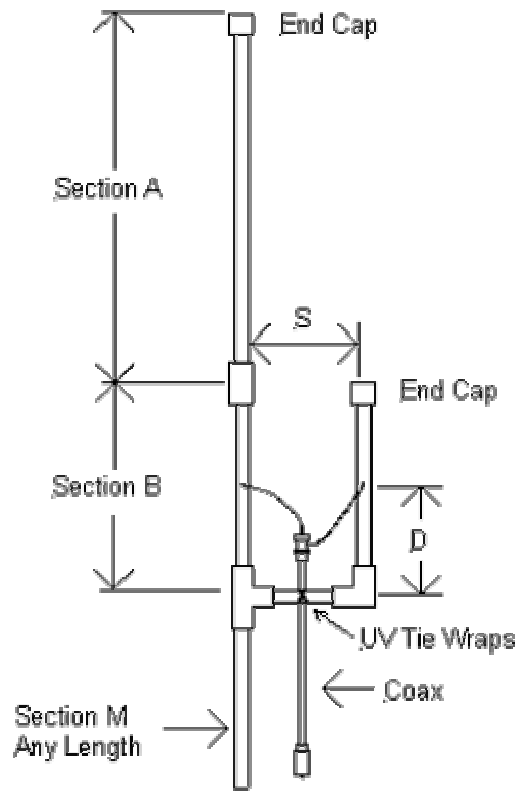


FIGURE - 1

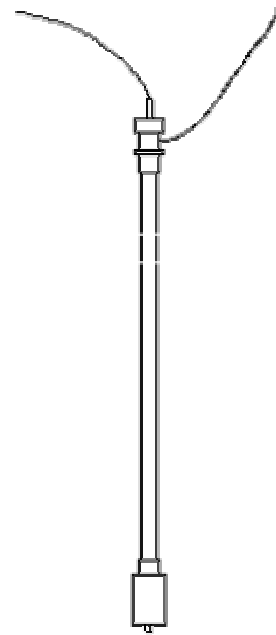


FIGURE - 3