A Convoluted Full-wave Loop Antenna 15

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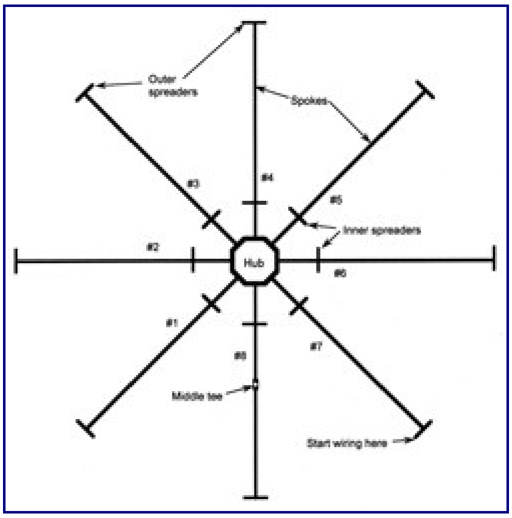
Here's a fun project that produces a novel looking antenna!

Photo of the CFL antenna mounted on a TV antenna rotator.



CPVC support structure for the CFL antenna.

Photo of hub and mast details.

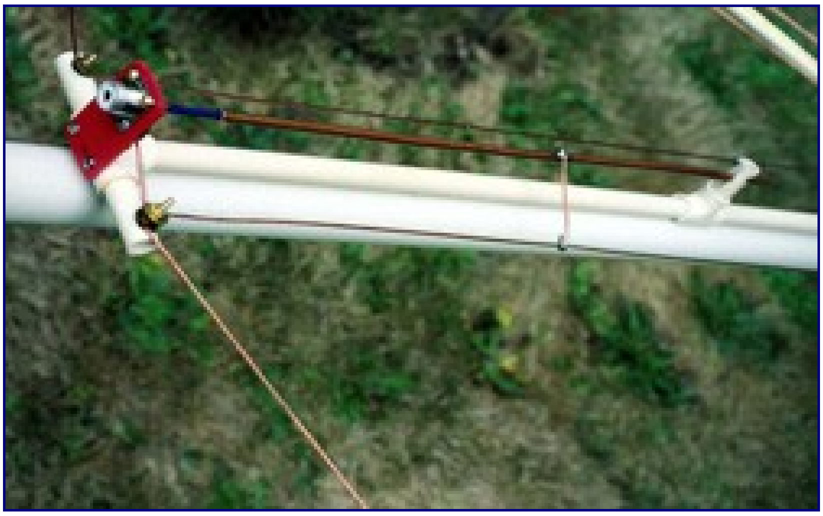
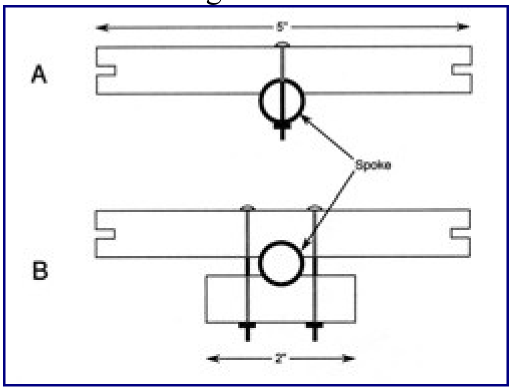
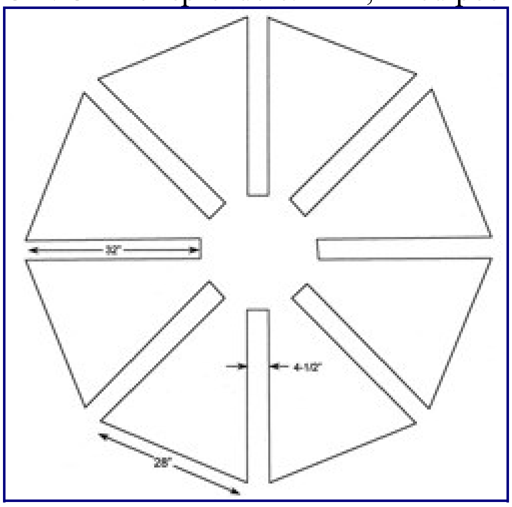


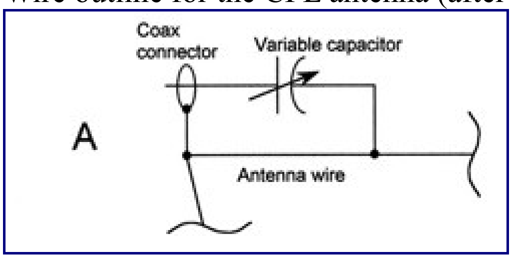
Photo of CFL's gamma match.

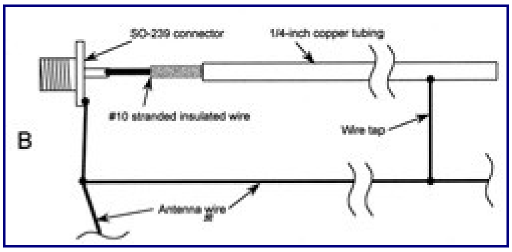


CPVC inner spreaders. At A, fixed position spreader. At B, movable spreader.

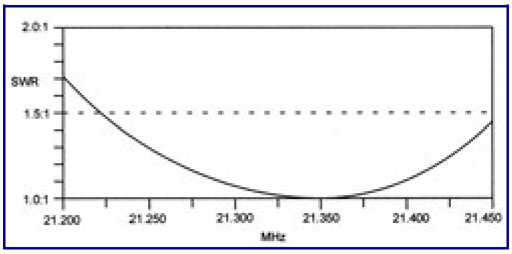


Wire outline for the CFL antenna (after K1KLO).

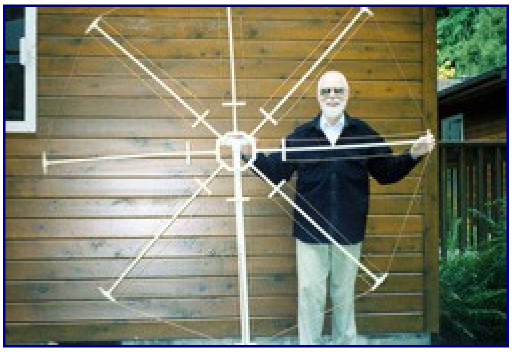




At A, gamma match schematic. At B, structure of CFL gamma match.



Graph of SWR of the 15-meter CFL antenna, showing coverage across the phone portion of the band.


The completed 15 meter convoluted full-wave loop antenna, with the author.

I have always been intrigued by miniaturized antennas, and ever since I read the March 1994 *QST* article by Andy Pfeiffer, K1KLO, entitled "The Pfeiffer Quad Antenna System," I have given his design considerable thought. The Pfeiffer Quad involved pulling the edges of a full-wave quad loop antenna in toward the center to form what Andy called a Maltese cross or Maltese double-cross quad. The antenna I describe below uses the double-cross octagonal configuration (see Figure 1).

I have been especially interested in developing antenna designs that anyone, especially new hams, could build. Therefore my objectives in designing miniature antennas, in addition to smaller size, have always been to make them lightweight, with the use of inexpensive, readily available materials. I wanted it to be easy to construct, without the need for machining or specialized tools.

I have long felt that polyvinyl chloride (PVC) water pipe, and its hot-water cousin, chlorinated polyvinyl chloride (CPVC), have a lot of these characteristics, as well as good insulating and dielectric properties. Therefore, I began designing a CPVC support structure for what I call the Convoluted Full-wave Loop (CFL) antenna, based on the pattern of K1KLO.

To keep the size and weight manageable, I selected the 15 meter band. This produced a 7 foot diameter antenna weighing 5 pounds, easily handled by a TV antenna rotator. I chose 1/2 inch CPVC for the support assembly, not only because of its small size, but because I felt the additional wall thickness, compared to 1/2 inch PVC, would hold up better over time. My original prototype, which has undergone a number of modifications, is still in one piece after about 10 years. The layout of the support system is shown in Figure 2.

The terms I use for the CPVC antenna support components are based on the antenna's similarity to a wagon wheel. The octagonal center is the hub; the eight long, radiating members are spokes, and the short crosspieces on the spokes are the inner and outer spreaders. The parts list, at the end of this article, details the components, their sizes and lengths.

Construction of the Support Structure

Since most of the CPVC parts are glued together, let me say a word about the cement. Three types of cement are available. PVC cement must be used with PVC parts only, and CPVC cement with CPVC parts only. However, a third type of cement may be used with either PVC or CPVC. I used a small can of the combination cement, since the mast was made from PVC pipe.

Pipe Glue — think before you fit

If you have never used PVC or CPVC cement to join the pipes to the fittings, be aware that it sets *very quickly*, in seconds. The usual procedure is to apply the cement to both surfaces to be joined, wait a few seconds and then quickly, using a twisting motion, push the pipe onto the fitting. You have less than 5 seconds to make sure the pieces are lined up the way you want them.

Glue the hub first, using eight Ts alternating with eight 45 degree elbows. You need 16 one inch lengths of CPVC pipe (hub connectors) to join them. The pipe is easily cut with a hacksaw, but be sure to clean off the resulting burrs around the edges. When a nipple is fully inserted into a given T and adjoining elbow, the nipple should be completely hidden, with the edge of the T against the edge of the elbow (see Figure 3).

Take care to ensure that all the Ts and elbows are in the same plane. To facilitate that, I temporarily inserted (without cement) some scraps of pipe, a foot long or so, into the Ts where the spokes eventually go. I found that it was easier if I made the hub in two halves and then joined those halves together.

Next make the spokes. Six of them (no. 1 through 6 in Figure 2) are identical. The outer spreader is made by cementing a two 1/6 inch lengths of pipe on each end of a T. Then cement this onto the end of a 37 inch spoke. Make six of these. Drill three clearance holes for 6-32 machine screws all the way through each one as follows: one on each end of the outer spreader — one 1/2 inch from the end and one 5 inches from the opposite end of the spoke. All of these holes are drilled at right angles to the plane of the structure. A drill press is useful, but not essential.

The no. 7 spoke is made the same as the first six, except that the hole on the spoke shaft is omitted. The no. 8 spoke is like the first six except that an additional T is inserted in the middle of the spoke. In its operational position, this is the lowermost spoke and will support the gamma match. Since the T will take about 3/4 inch out of the spoke, cut the two pieces that make up the spoke 18-1/8 inches each. The middle T should be glued at right angles to the outer spreader T. Drill this spoke the same as the first six.

Glue the eight spokes into the eight Ts of the hub in the order shown. Make sure that the outer spreaders are in the same plane as the hub. The middle T in spoke no. 8 is at right angles to the spreaders, as shown in Figure 2 and the photo in Figure 4.

You can make the eight inner spreaders several ways, depending on available equipment. Each is 5 inches long with a slot 1/4 inch deep by about 1/8 inch wide cut in each end (see Figure 5A). A rounded notch is cut into the center of the spreader about 1/4 inch deep. This notch fits over the spoke, and since the pipe is 5/8 inch outside diameter, I used a 5/8 inch straight bit in my table router to cut the notch. However, you could file it with a large, rat-tail rasp or even cut it with a saw. Since the only purpose of the notch is to keep the spreader at right angles to the spoke, it really isn't essential, but it makes the final assembly a little easier. To complete the spreader, drill a 6-32 clearance hole through the center of seven of these inner spreaders, down through the middle of the notch. Secure the seven spreaders to the seven spokes that have the spoke hole drilled, using 6-32 ´ 1-1/2 inch brass machine screws.

The last inner spreader goes on the no. 7 spoke and is made so that it can be moved along the length of the spoke (Figure 5B). This allows the total length of the loop wire to be adjusted to find the desired resonant frequency. Instead of one hole in the center, drill two holes about 7/8 inch apart, one on each side of the notch. A second piece, the inner spreader connector, is 2 inches long but notched and drilled the same as the spreader. Insert two no. 6-32 ´ 1-3/4 or 2 inch brass screws, one on either side of the spoke, through both the spreader and the connector. Add nuts, thus forming a clamp. The spreader is moved by loosening the nuts and sliding it along the spoke. Initially, place this movable inner spreader at the same position as the other inner spreaders.

The Mast

A mast isn't necessary if you plan to support the antenna in some other way, such as hanging it from a tree. But if you plan to use a mast, make it at this time and secure the support structure to it. I made the mast from 1-1/4 inch, schedule 40 PVC pipe, 4-1/2 feet long. To give the lower part of the mast additional strength, I glued a 2 foot length of 1 inch, schedule 40 PVC inside the base of the mast. It was an easy, but snug, fit. On the other end glue a 1-1/4 inch T with two 3-1/2 inch lengths of 1-1/4 inch, schedule 40 PVC glued in (see Figure 3).

To fasten the support structure to the mast, use two no. 10-32´ 1-1/2 inch stainless steel machine screws, inserted through clearance holes in the hub and through one thickness of each of the arms on the T, as shown in the photo. The two screws are 6-1/2 inches apart. To provide additional stability, I added two no. 10 ´ 1-1/2 inch stainless steel tapping screws, one at the bottom of the hub and one through the T of the outer spreader of spoke no. 8, and screwed into the mast.

Wiring

Once all the spreaders and the mast are in place, insert no. 6-32 ´ 1 inch brass machine screws in the outer spreaders and secure them loosely with a flat washer and nut. You are now ready to string the wire. I used 14 gauge bare stranded antenna wire. RadioShack sells a 70 foot roll, which is just enough for this antenna.

Referring to Figure 6, form a small loop in the end of the wire and put it under the nut and washer on the left screw on the outer spreader of the adjustable, no. 7 spoke (see Figure 2). Tighten the nut snugly and take the wire to the nearest screw on the next (no. 8) spoke outer spreader. Measure the wire so that with it stretched out 28 inches separates the two screws on the adjacent spreaders. Put a 90 degree bend in the wire, slip it under the nut and washer and tighten the nut. Because the spokes are fairly flexible, it is not possible to keep the wire taut, but don't worry since that will be taken care of later.

Stretch the wire to the inner spreader on the no. 8 spoke, slip it into the notch in the spreader and make another 90 degree bend. Take it over to the other side of the inner spreader and through the second notch, again with a 90 degree bend. Draw the wire taut down to the remaining screw on the no. 8 outer spreader, make a 90 degree bend and secure the wire under the washer and nut.

Take the wire to spoke no. 1 and continue the process from spoke to spoke, clockwise all the way around the structure until you get back to the starting no. 7) spoke. You can now draw all the outer wires up taut as you secure the last outer part of the wire to the no. 7 outer spreader. Don't draw it up too tight, however, or it will cause the spokes to bend and the structure to buckle. Continue on with the wire around the no. 7 inner spreader, making another small temporary loop, and secure the wire under the nut and washer on the screw you started with. Leave about a foot or so of extra wire on the loop, wrapping it back around the tightened wire. The full-wave, closed loop is now complete.

Feeding the Antenna — the Gamma Match

The loop antenna may be fed directly by opening the loop at any point and inserting a coax connector. However, the SWR will be rather high even at the resonant frequency, so a gamma match is used to correct this. The gamma match circuit is shown in Figure 7A. It consists simply of a variable capacitor across a portion of the antenna. The SWR is reduced to minimum by adjusting the variable capacitor and the length of the portion of the antenna wire making up the gamma match.

I devised a simple homemade gamma match for this antenna. The capacitor is composed of an 18 inch length of 10 gauge stranded, insulated wire inserted inside a similar length of 1/4 inch diameter copper tubing (Figure 7B). You can obtain this wire in small quantities at auto parts stores or auto electric garages. Many hardware stores sell the copper tubing by the foot.

You vary the capacitance by sliding the wire in or out of the tubing. A very thin coat of grease on the wire will make the sliding easier. When fully meshed, its capacitance is about 120 pF. To keep rainwater, dirt and bugs out of the tube, I crimped and soldered shut the open, upper end. The capacitor is mounted on the no. 8 spoke, parallel to it. see Figure 4.

To install the gamma match, first secure an SO-239 chassis-mount coax connector to the outer end of the no. 8 spoke with a small, homemade bracket about a 1 inch by 2 inches. I used a scrap of 1/8 inch thick plastic for ease of drilling, but any non-corrosive material will work. Drill the holes for the connector and mount it with four no. 6-32 ´ 1/2 inch brass machine screws. The two holes for the tapping screws that hold the bracket to the outer T of the spoke should be about an inch from the edge of the connector. Attach the bracket to the outer side of the T with two no. 6 ´ 1/2 inch stainless-steel tapping screws. The coax connector supports the one end of the capacitor.

Support the other end with a 1-1/2 inch length of CPVC pipe. Drill a 1/4 inch clearance hole all the way through the pipe about 1/2 inch from one end and cut a slot in the end of the pipe down through the 1/4 inch hole and beyond by about another 1/4 inch. Drill a no. 6-32 clearance hole at right angles to the 1/4 inch hole and between it and the short end of the pipe.

Insert the copper tube through the 1/4 inch hole in the support piece and put a no. 6-32 ´ 1 inch brass machine screw with a nut in the smaller hole. Don’t tighten the nut yet. Insert the longer, unslotted end of the support piece into the middle T in spoke no. 8, without glue. Slide the wire and tube down and solder the exposed end of 10 gauge wire to the coax connector center pin. Then go back and glue the support piece into the T.

The body of the coax connector is attached to the antenna wire immediately to its right by running a short piece of wire, just a few inches long, from the screw holding the antenna wire over to the closest coax connector screw. Finally, there will be a tap that runs between the copper tube and the antenna wire to the right of it. That will be described below.

Adjustments

There are three adjustments to be made, in this order: (1) the overall length of the antenna, (2) the variable capacitor and (3) the length of the portion of the antenna used in the gamma match — that is, the position of the tap running from the copper tube to the antenna wire. You will eventually solder the tap in place, but initially use a temporary tap. I made one by close wiring two alligator clips together, back-to-back. I clipped one on the antenna wire and the other on the tube. Be sure that the clip is large enough to grip the tube without forcing it. To start, position the copper tube so that it covers all but an inch of the 10 gauge wire and tighten the no. 6-32 nut on the support piece, clamping the tube in place. Place the temporary tap about 12 inches from the body of the coax connector.

To adjust the overall length of the antenna, first find its resonant frequency. I used an MFJ-259B antenna meter, which made the job relatively simple. However, you can achieve the same result by using a grid dip meter or by applying a very minimal CW signal (less than 1 W if possible) and checking the SWR at various frequencies. (Be very careful that you don’t interfere with other stations. A good time to carry this out is when the band is not open.) If you have constructed the antenna close to the measurements given, the minimum SWR should be somewhere in the middle of the 15 meter band. To increase the resonant frequency, shorten the antenna by loosening and sliding the adjustable inner spreader away from the hub. Then reposition and refasten the end of the antenna wire. I wanted to use my antenna on the phone band so I had to move the spreader away from the hub a couple of inches.

Note that the proximity of the antenna to the ground will affect the resonant frequency (as well as the SWR). Initial readings may be made with the near the ground but the final adjustments should be made at or near the final operating position of the antenna.

Once you achieve the desired resonant frequency adjust the gamma match. I found that the position of the wiretap was somewhat more critical than the setting of the capacitor. By playing with these two adjustments you should be able to achieve a perfect 1.0:1 SWR at the resonant frequency. Once you have a satisfactory SWR, replace the temporary alligator clip tap with a wire soldered to the copper tube and the antenna wire. Trim the excess wire from the main antenna loop and solder the two ends of the loop together.

Performance

Any shortened compact antenna is not going to be as broadband as a full-sized antenna. However, the SWR for this antenna was less than 1.5:1 across almost the entire phone portion of the 15 meter band. see Figure 8.

When I made the first CFL 15 meter prototype, I temporarily stuck it onto a short tripod in my yard, which put the bottom of the loop about 2 feet above the ground. After a few preliminary adjustments, I worked a station in Argentina! Eventually I used the antenna on a crank-up tower, up at about 35 feet at the hub. Since I don't have the facilities for testing antenna performance in any precise way, I could only go by signal reports while transmitting and my S–meter readings while receiving. I compared these readings to those obtained with my Mosley Pro-57-A beam, which is up about 55 feet on a separate tower. The reported S-meter readings were generally 1 or 2 S-units higher with the beam. Of course, the CFL antenna is not a beam; it is a single element.

The final result of this project has been the design and construction of a very lightweight, very functional antenna (Figure 9). It can be supported and turned with a TV antenna rotator and can easily be built with a minimum of expense by the rankest of novices.

Future Designs

It was fun designing and building this antenna and it has opened up a number of possibilities for variations. What about adding a second (or even a third) element? Electrically this should definitely improve performance but the structural problems would be challenging.

Then there is the question of CFL antennas for other bands. Constructing similar antennas for 12, 10 or 6 meters should be easy, but going the other way to 17 or 20 meters would present more of a structural challenge. A similar 17 meter antenna would be a bit over 8 feet in diameter, while a 20 meter antenna would be close to 10 feet across. Making these should be possible using schedule 40 PVC, but the weight and wind loading would probably preclude the use of a TV antenna rotator. On the other hand, the need for a rotator is questionable anyway.

I have also pondered the idea of a multi-band CFL antenna. Could traps be introduced across segments of the radiator to electrically shorten it and make it resonant at other frequencies? Feeding it might be a problem. Or could shorter radiators be "nested" within the larger radiator, as in a triband cubical quad? And the list goes on.

Most of us who are not electrical engineers have long since been left in the dust when it comes to designing or building SSB rigs, but working with antennas still provides us with a lot of interesting territory to explore!

CPVC parts:

- 1/2 inch pipe: (10' lengths): 4
  - Spokes (37"): 7
  - Spoke no. 8 (18-1/16"): 2
  - Inner spreaders (5"): 8

        - Inner spreader connector (2”): 1
        - Outer spreaders (2-1/16”): 16
        - Hub connectors (1”): 16
        - Gamma match support (1-1/2”): 1
    - 1/2” Ts: 17
    - 1/2” 45° elbows: 8

Mast

- 1-1/4” schedule 40 PVC pipe (6’):
    - Vertical part (4-1/2’): 1
    - Horizontal parts (3-1/2”): 2
- 1-1/4” PVC T: 1
- 1” schedule 40 PVC pipe (2’): 1

Wire, 14 gauge copper antenna wire (65’)

Screws, machine, brass or stainless steel

- 6 ′ 1/2”: 4
- 6 ′ 1”: 17
- 6 ′ 1-1/2”: 7
- 6 ′ 2”: 2
- 10 ′ 1-1/2”: 2

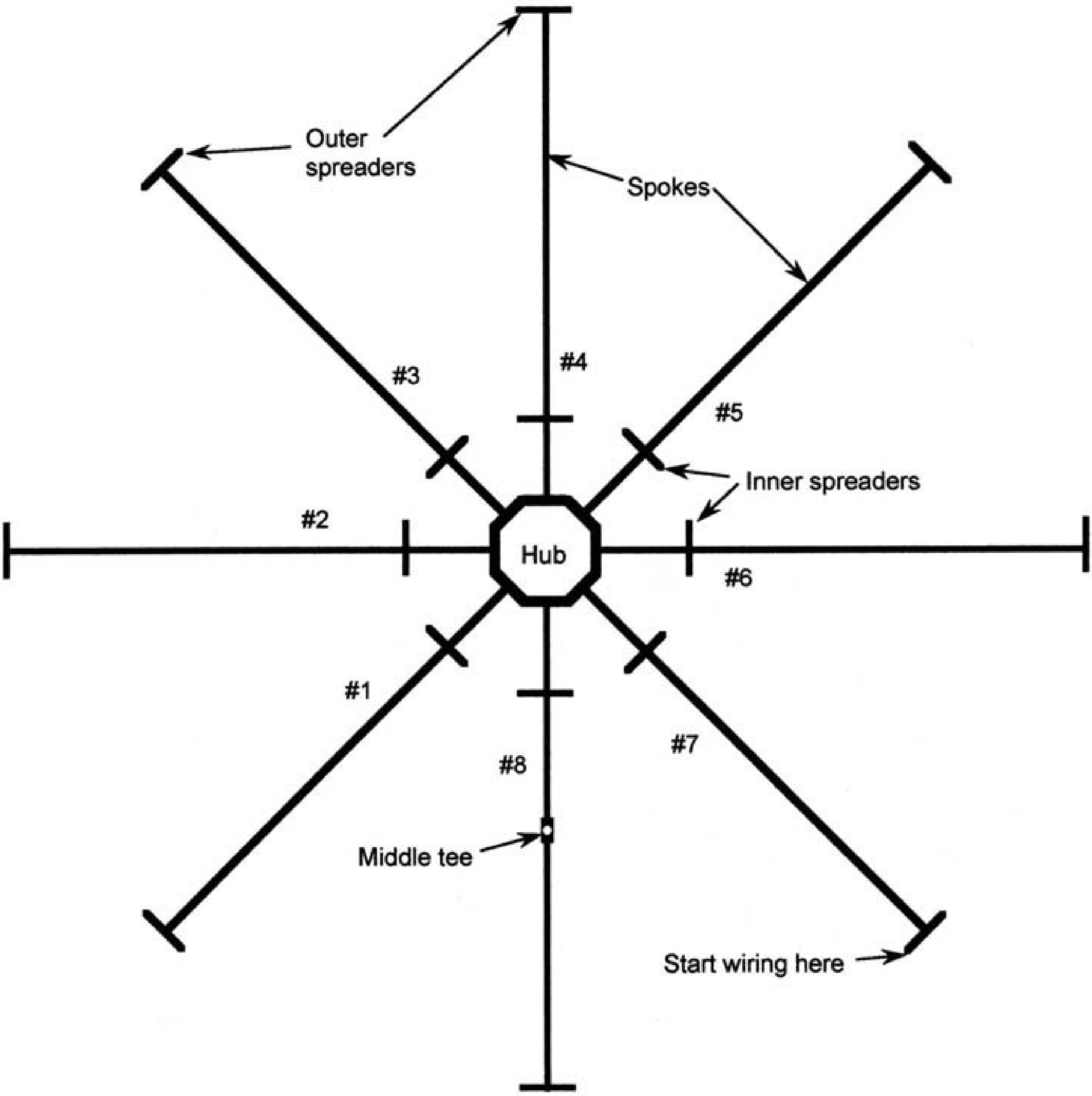
Screws, tapping, stainless steel

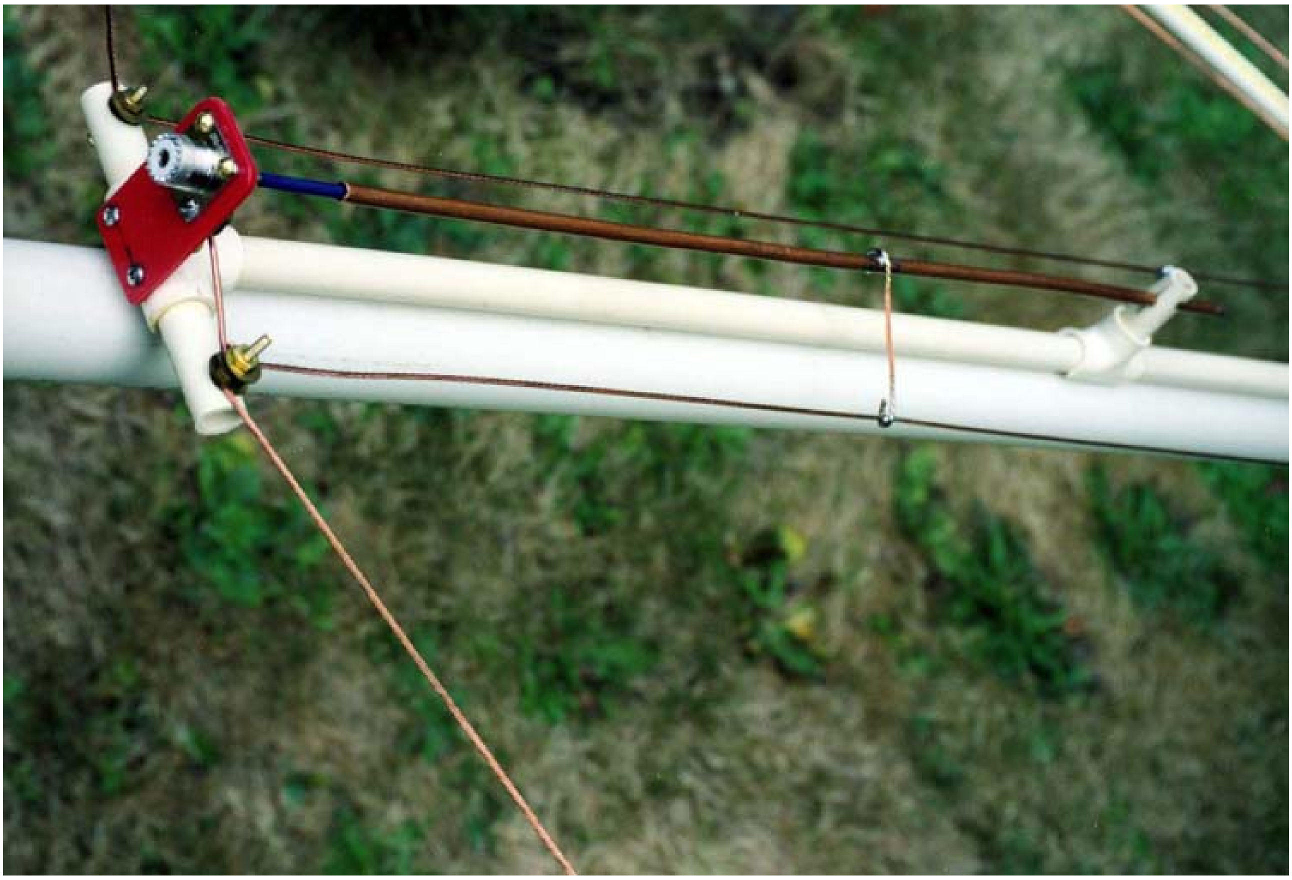
- 6 ′ 1/2”: 2
- 10 ′ 1-1/2”: 2

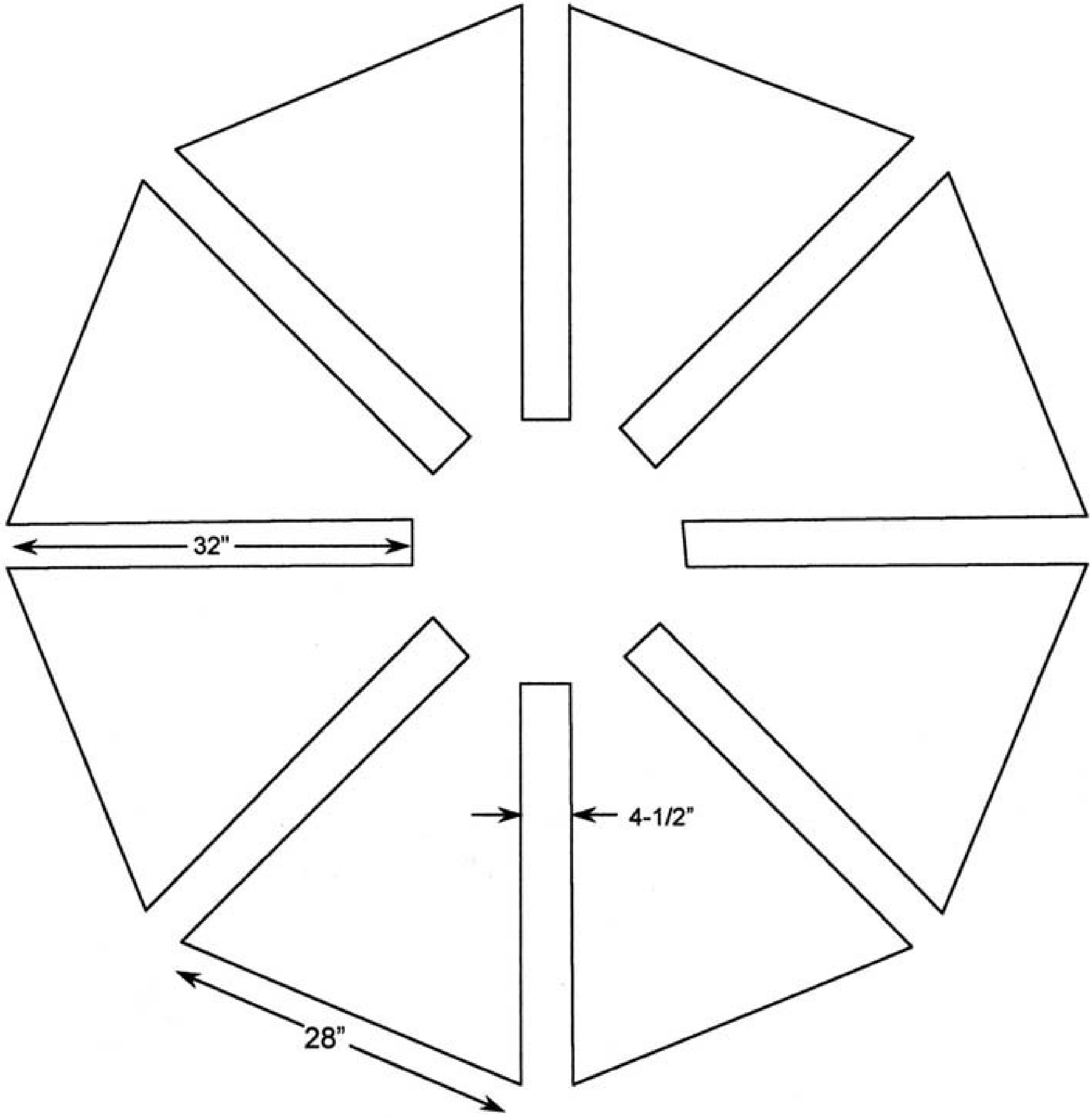
Gamma match parts

- SO-239 chassis mount coax connector: 1
- Connector mounting plate (see text): 1
- 10, stranded insulated wire: 18”
- 1/4” diameter copper tubing: 19”
- Shorting bar, any bare copper wire: 3”

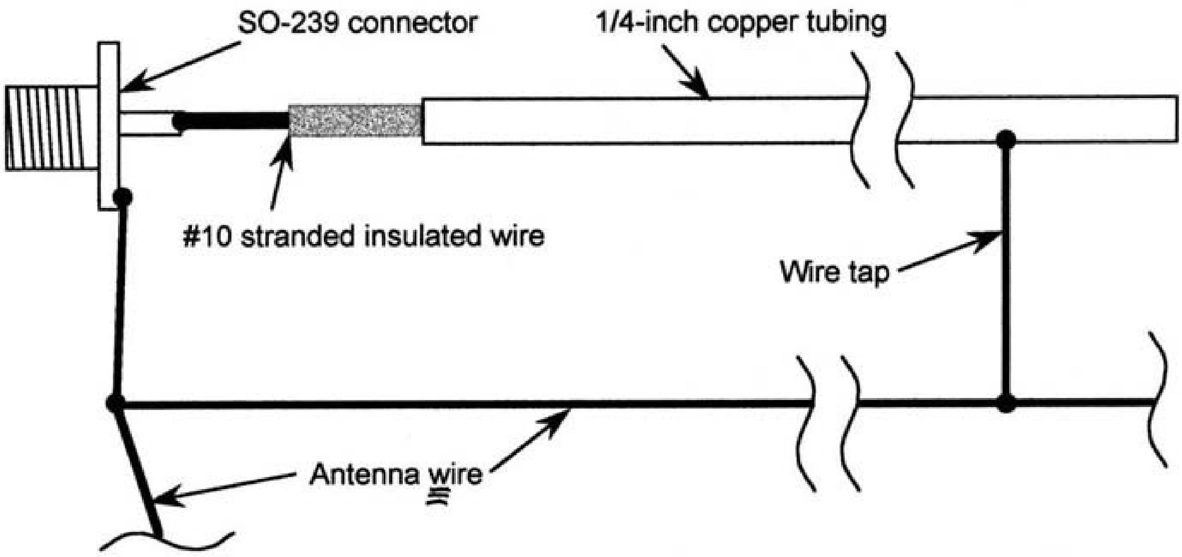
All photos courtesy of David Shortess, W7PTL


Outer
spreaders
Spokes
#3
#4
#5
Inner spreaders
#2
Hub
#6
#1
#7
#8
Middle tee
Start wiring here




32"
4-1/2"
28"

B


SO-239 connector
1/4-inch copper tubing
#10 stranded insulated wire
Wire tap
Antenna wire