Tinker Toys for Adults
Some Notes and Ideas on PVC for Antenna Applications

L. B. Cebik, W4RNL

Part 1: General Notes on Working with PVC

Every since I called PVC "tinker toys for adults," the phrase has gained popularity (except among the erector set and "lego" generations). The material is extremely versatile for amateur radio applications ranging from operating furniture to antenna supports. It cuts with a simple saw, glues eternally, and may last a long, long time. However, it also has some pitfalls and inconveniences. Only experience and creativity limit the ways we can put it together to form useful ham items. My interest is chiefly in antenna applications, but other uses abound.

The following notes are taken from several dozens of projects in which I have used the material in various ways. They do not form a comprehensive list of uses, Instead they are one of many possible starter collections to whet your appetite and your get your own creative juices flowing.

What is PVC?

PVC (poly-vinyl chloride) is a plastic material most usually formed into tubes and associated junctions. It is used extensively in plumbing in its white form and in electrical conduits in its gray form. The difference between colors can be important, depending on where you live. Apparently, there is no clear nationwide uniformity in the exact formulation of the material, so long as it meets certain specifications. The gray form seems everywhere to include a healthy dose of UV-protectant material, while the white form is more variable. In the Southeast, the white form tends to contain more UV-protectants and lasts a long time in outdoor use. In the Northwest, the white form tends to contain less UV-protectants and becomes brittle more rapidly in sunlight. (The white form available in Tennessee is quite durable in continuous sunlight, as some 10-year-old yard benches, arbors, and birdhouse supports all attest.) Hence, before choosing a PVC form to use, check with local experience.

For most uses that are continuously exposed to daily sunlight, about 10 years is a maximum lifetime, even for UV-resistant forms of PVC. Assuming that you perform annual preventive maintenance on your exposed structures, you can detect increased brittleness

from the sound made when a tube is tapped. The dull thud of new PVC becomes a sharper rapping sound. When in doubt, replace the length: PVC is amongst the cheapest material available for construction. If your interests include gardening, then 1 1/4" to 1 1/2" nominal PVC can be used to make up the framework of a greenhouse and its integrated work benches.

The primary family of PVC tubing and fittings used for most projects is likely to be Schedule 40. This family consists of tubes that are listed in nominal diameters, where "nominal" means that the inside diameter is at least the size listed. Typically, Schedule 40 tubes have walls that are roughly 5/32" thick. The following table lists some common sizes and their inside and outside diameters--as measured informally.

Schedule 40 Dimensions (in Inches)

Nominal Size	Inside Diameter	Outside Diameter
1/2	9/16	7/8-
3/4	3/4+	1 1/16
1	1	1 5/16
1 1/4	1 5/16+	1 5/8+
1 1/2	1 9/16	1 15/16

Note: + and - correspond roughly to woodworker measurements called "strong" (a bit over, but not enough to call for the next increment) and "weak" (a bit under).

The are other diameters of Schedule 40 PVC tubing, roughly in half-inch increments (nominal). Above a certain diameter, we may tend to call these "pipes." Many can be used for in-ground supports for masts and pipes. Our interest, though, is mainly in joining sections into assemblies, so we shall let the big sizes be an exercise in your own creativity.

From the table, we can immediately see one of the inconveniences of Schedule 40 PVC: it does not nest, one size inside the other. The one exception is 1" and 1 1/4" tubing, which will loosely nest. However, the gap is such that a glue connection will not be secure. Nuts and bolts make the best link.

In place of nesting sizes, there are fitting galore, some of which are intended to link tubing of the same size and others of which are intended for permit joining two different sizes of tubing. So all is not lost.

Before we move on to junctions of tubing, let's note that within the PVC umbrella are a number of other types and sizes. For example, CPVC is available. It is a thin wall (about 1/32") tubing whose dimensions are closer to copper piping. 1/2" nominal CPVC has an inside diameter of about 1/2"- with an outside diameter of about 9/16". I have successfully used this material in relatively unstressed or very low load conditions. For example, I have used it as 4.5' spacers for a 10-meter wire beam and as spacers to separate the ends of tubular Moxon rectangle elements to keep them aligned.

Also available are other families of white PVC. Schedule 80 PVC is sometimes available, but usually not in the common home center. A thinner-wall white PVC is more readily available. One common designation is SDR 21, although you may encounter other notations. It has the same outside diameter as Schedule 40 for the same nominal size. However, the wall is only about 3/32" thick. Hence, 1/2" nominal SDR 21 has an inside diameter of 11/16" and 3/4" nominal has an inside diameter of about 15/16". For many

VHF projects, this thinner PVC may be adequate to support an antenna, although it is weaker and more flexible in longer lengths. For example, some aluminum rods shipped to me inside a 5' long 1 1/2" nominal SDR 21 tube arrived intact, but the tube had been cracked somewhere along the route. Schedule 40 would not have cracked, but would have cost considerably more in shipping charges. Do not underestimate the weight of Schedule 40 PVC.

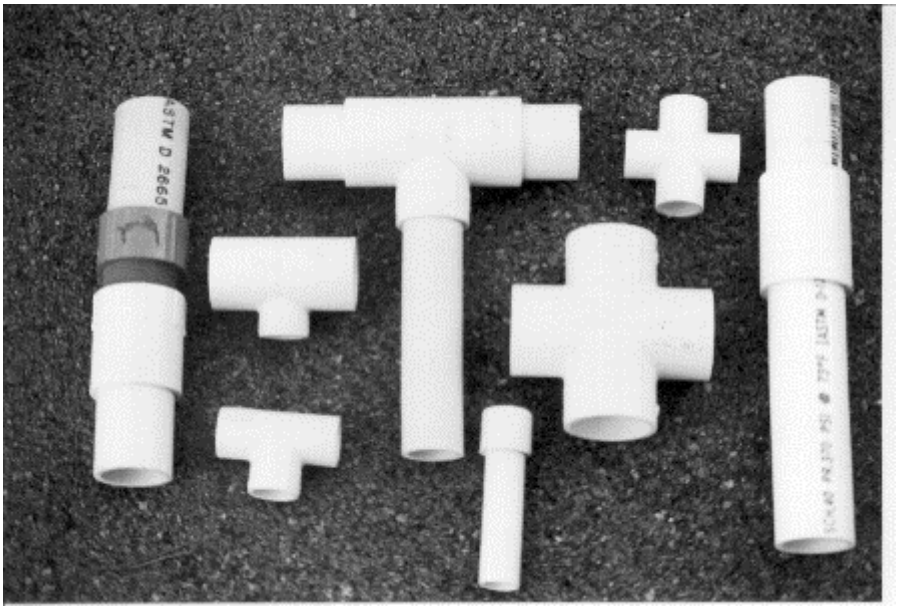
Connecting Lengths of PVC

As we earlier noted, only the 1" and 1 1/4" nominal sizes of Schedule 40 PVC nest, and they tend to require nuts and bolts to secure the junction. I have built portable masts with up to three 5' sections by alternating the two sizes, with stove bolts securing the assembly. However, there are better ways.

The two chief forms of junctions pieces are the glue and the screw joints. Since every joint requires at least some gluing, let's begin with them. Gluing is more properly called cementing, and the process requires two steps. There is a joint cleaner, usually blue or purple, that prepares the surface for mating with a junction fitting. Many hams skip this step, since the joint need not be as water-tight as a plumbing joint. However, it is always recommended.

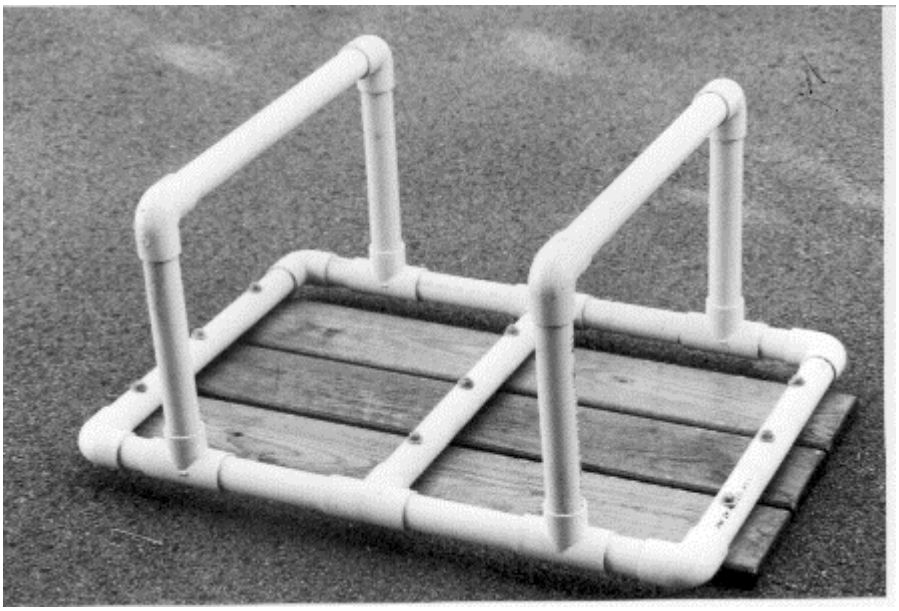
PVC cement actually fuses the two surfaces of the pieces to be mated. Depending on the amount of cement used, you have between 15 and 30 second to fit and align a joint before the two surfaces become a single solid. Hence, it pays to have pre-prepared jigs for aligning multiple joint structure, such as a U-shaped assembly. Often, simply locating good straight surfaces is sufficient for the job of alignment. For example, I use my shop floor and workbench legs to align right angles with enough precision for most applications.

Once glued, the connection is permanent. If it is not right, cut off the junction and use other junctions and tube pieces to replace the cut-out section. Be sure to wipe off each junction immediately after gluing to keep the exposed surfaces clean and smooth.



1 A collection of PVC junctions from my junk box.

Glue junction pieces come in many types: in-line, 90-degree Ls (or elbows), 45-degree elbows, Tees, Ys (with a side 45-degree piece), (4-arm) crosses, and caps. **Fig. 1** is a casual photograph of some of the junction types from my junk box. Some combination of these fitting will let you create triangles, squares, and octagons suitable for yard furniture.



2 A bottom view of a yard bench illustrating some PVC assembly techniques.

See the photos of an inverted yard bench (**Fig. 2**) and a gurney (**Fig. 3**) used for my YL's wild bird rehabilitation cages.

3 A wild bird rehabilitation cage gurney showing additional PCV construction techniques.

The photos also reveal another secret of PVC. We can install junctions--usually 90- degree Ls and Tees--wherever we need to change direction. Since each fitting is limited in the number of junctions available, our designs must offset each junction that changes the direction of the tubing. Between each junction, we must use a link piece of tubing. The link

tubing between two adjacent junction fittings may not be visible in the finished product, because it is cut to exactly twice the inset depth of the fitting. However, it is a necessary element in the structure: it serves as a glue surface for the junction pieces, and it doubles the total thickness of PVC at these junction stress points.

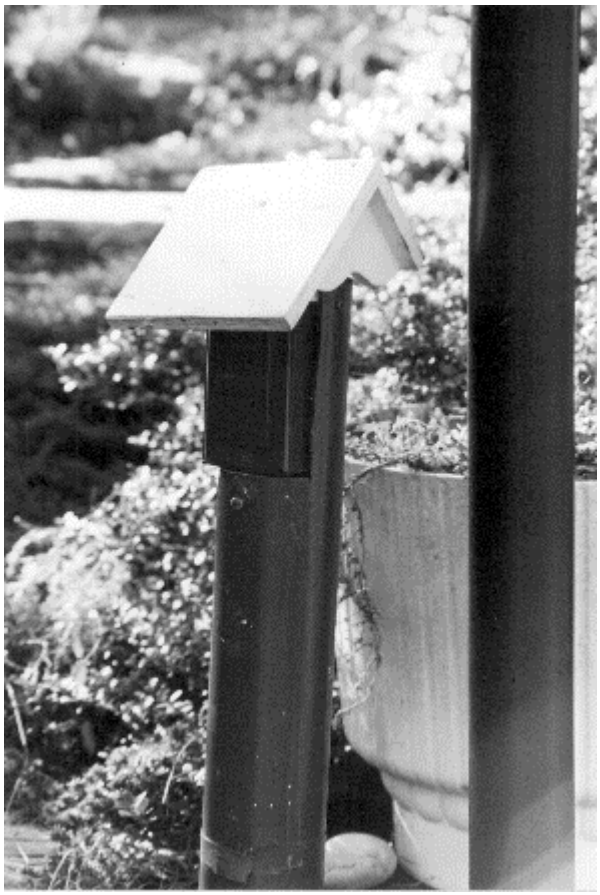
Screw joints are handy for joining sections of tubing that you may wish to take apart later or which may serve multiple functions. Each screw joint consists of a male and female section, and each of these is glued to their respective lengths of tubing. Then, the two assemblies are simply screwed together.

Screw sections are available for changing tubing sizes. In fact, there are Tees with a side screw section in smaller sizes. Hence, you can have a vertical support with a removable "handle" for turning. One note of caution. The gray PVC screw fittings, designed to connect sections of electrical conduit, may not be as substantial as the white equivalents. For example, the locally available male gray screw section has a thinner wall than its white counterpart. In the 1 1/4 nominal size. the white version fits over the swaged end of common 1.25" steel masting, and wedges nicely onto the full diameter section. The thinner-wall gray equivalent simply slides over the full diameter of the mast. Once more, check your local supplies and test fit everything before buying, since there may be regional variations on the available stock.

Every glue job usually requires some tube cutting to a specification. PVC cuts well with a simple hack saw. You should take time to deburr the edges, including a good rub of the corners with medium sandpaper. Dry-fitting joints is not only unnecessary; it sometimes is disastrous. I have a few dry-fit junctions around that act as if they were glued. Just be sure the junction areas are clean and evenly cut for a good fit with cement applied.

If you have a motorized shop, then a "chop" saw is very good for cutting PVC--with a couple of precautions. First, clean the blade after every use for PVC is you wish to get clean wood cuts later. Second, be sure to use hold-downs of some sort for each side of the cut. The saw can spit out the shorter cut end at a very damaging rate. I tend to make my cut and let the blade brake to a stop before raising the saw. Of course, safety glasses are mandatory, and gloves are recommended. Also, beware of cutting well-aged and more brittle PVC tubes: the shrapnel can be painful. Hand tools are slower, but rarely create the danger levels of power tools.

PVC also drills easily. A starter hole created by an awl helps to prevent drill-bit skidding. a drill press is useful here, but rarely mandatory. However, a jig or vise to hold the tube is often the key to a neat job. You can also cut slots in the end of PVC. In fact, some applications may involve a combination of slots and drilled holes at their inner ends. For very large diameters of tubes, you can use a saber saw (which are now called jig saws, and the old jig saw is now called a scrolling saw, even though saber saws may have scrolling features.) See **Fig. 4** the photo of the outdoor electrical outlet post for an example of this technique.



4 One way to add an outdoor outlet in your yard using a PVC post.

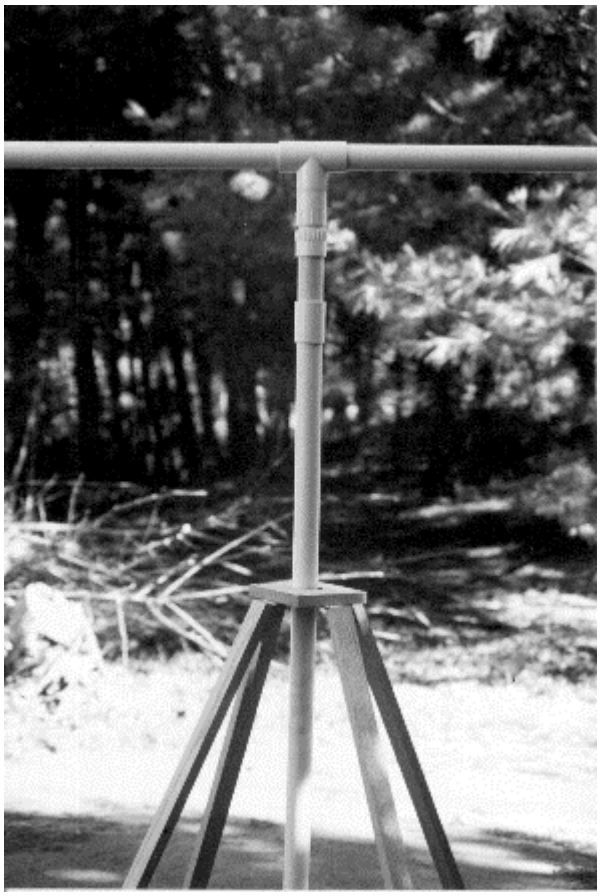
Although we shall focus on PVC alone, do not hesitate to look throughout your home center for metal fittings that you can join with sheet metal screws or with nuts and bolts to a PVC framework. You can solder or braze other metal to a copper plumbing pipe cap and add a solder lug or other connector. Some metal parts may require a bit of work to make a good mechanical junction with PVC, but the possibilities are almost as endless as the hardware supplies in home centers.

You may wish to compare these general notes with the materials available in your area. Modify the notes to reflect what is true of PVC to which you have access. Now let's look at some distinctly ham applications of PVC.

Part 2: Some Ham Applications of PVC

Let's divide our applications into several categories: masts, booms, element supports, and storage. We shall omit other uses of PVC--for example, as a coil form or as a chair frame--for another time.

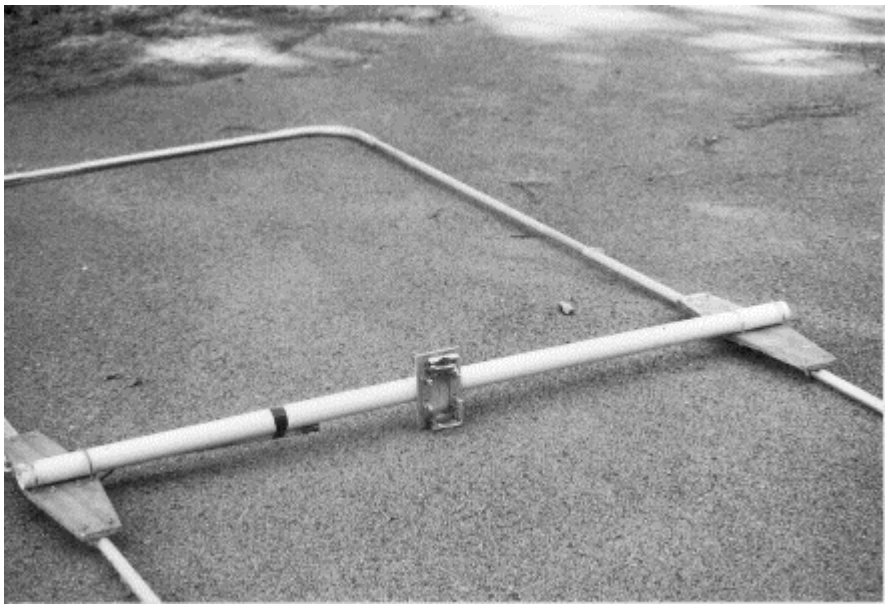
1. Masts: My best general recommendation: don't. There is a temptation to use 10' lengths of PVC for masting. My personal experience suggests that even Schedule 40 PVC sags and sways too much compared to other available materials. 5' lengths can be coupled with less sag and more convenient transport. However, they tend to be heavier than common 5' 1.25" TV masting of the same length--and the TV masting shows less sag and instability when raising it from the horizontal to the vertical position.



5 A beam mounted on a PVC mast mounted in my shop antenna assembly jig.

However, using a 1 1/4" 5' section with a screw coupling at the top is convenient for workshop use. In fact, I tend to keep all PVC lengths at 5' and under, since they bundle and fit both my pick-up and may more easily. The photo in **Fig. 5** shows part of a small beam under construction outside my shop. The short mast lets me assemble the antenna parts comfortably.

2. Booms: The photo (**Fig. 6**) of the boom structure of the Moxon rectangle shows one way to use 1 1/4" PVC as a boom. Beyond the 5' length, PVC tends to sag too much for effective boom use. However, in the shorter lengths, it hands very much like an aluminum boom--with one advantage: the elements are automatically insulated (or, more properly, isolated) from metal structures.



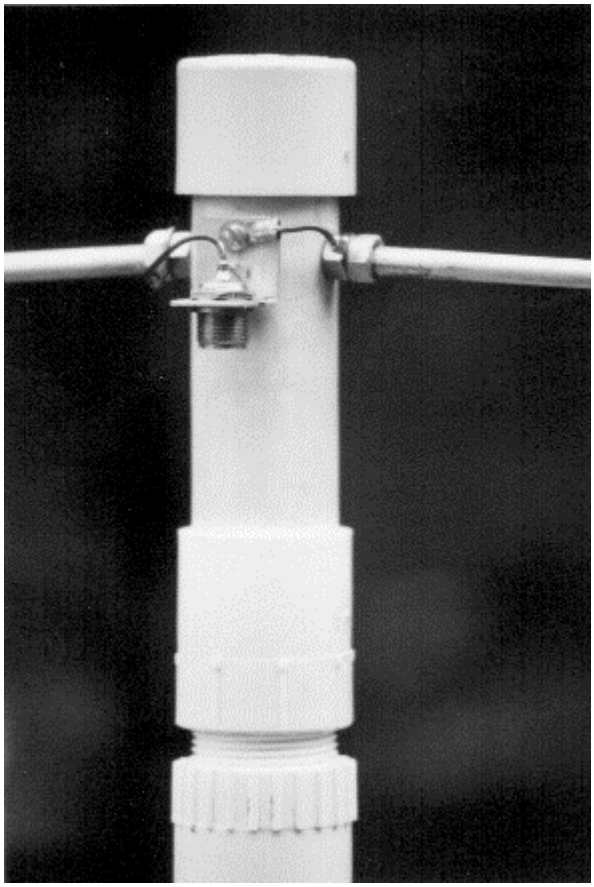
6 A Moxon rectangle using a PVC boom with element and boom plates.

I have not detected any RF conductivity in Schedule 40 PVC in the HF range. Hence, its use to support elements can be easily recommended. Whether or not PVC has any conductivity at VHF is a question for which I have not seen any definitive data. As we shall see, there are ways of using PVC to support VHF elements that will tend to minimize any possible interaction, just in case at least some formulations are RF conductive above the HF range.

7 A portable dipole with a PVC hub and screw fitting, mounted on a steel mast.

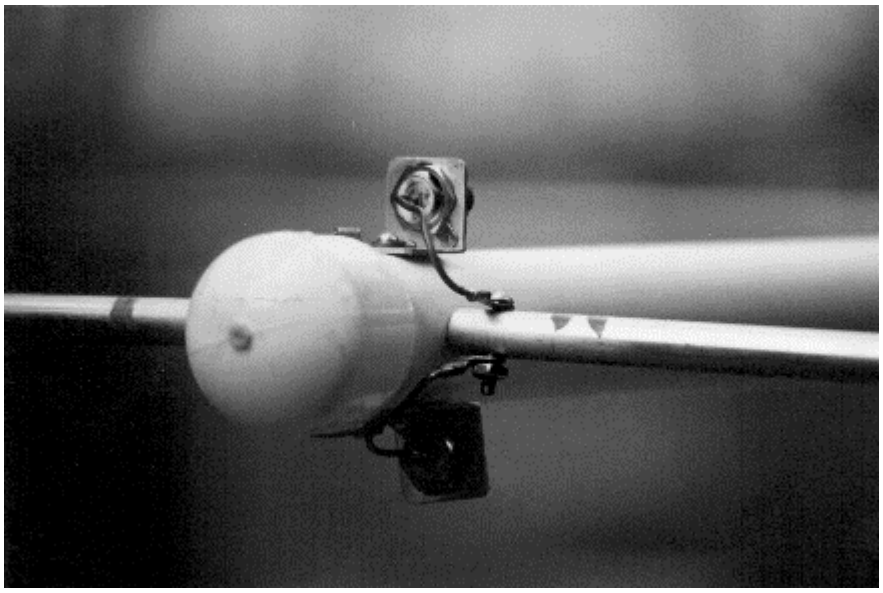
A second form of boom is used with my dipole in a tube and my beam in a boom, both of which have been published in the *ARRL Antenna Compendium*, Vol. 6. The center hub of the dipole and the boom of the beam terminate in a screw fitting. A short section of tubing with a male fitting permits the short mast to fit over the end of a standard section of TV mast and to wedge in place for portable use, as shown in the photo in **Fig. 7**. You can

wrap the TV mast with a few layers of electrical tape where the short PVC stub just fits on top. This move will keep the antenna-and-PVC portion stable. No additional clamping is necessary for the usual short- term portable operating session, but for longer periods at height, you may wish to add a stove bolt through the joined sections to keep the wind from turning the assembly without turning the mast.



8 A close-up of a PVC dipole element hub for aluminum rod elements.

The elements for there two antennas represent two (of many) different ways of mounting elements. The rod elements are threaded, as shown in one close-up photo (**Fig. 8**), and simply bolt in place in the end of a section of 1 1/4" nominal tubing, using nuts both inside and outside the tube. The 10-meter rod elements can be replaced with eye-screws and a large solder lug for attaching wires for ant band. As shown in **Fig. 9**, the tubular beam elements fit over a 3/8" diameter fiberglass rod and are held in place with #8 stainless steel nuts and bolts. In both cases, I dry fit a PVC cap over the end of the tubing. The cap functions mainly to remove stresses from the elements that might eventually deform the PVC. (As a plastic, PVC retains some fluid properties and may be deformed over time by a continuous set of pressures.) We shall look at another cap function a bit later.



9 A close-up of a PVC boom with details of the aluminum tubing element assembly.

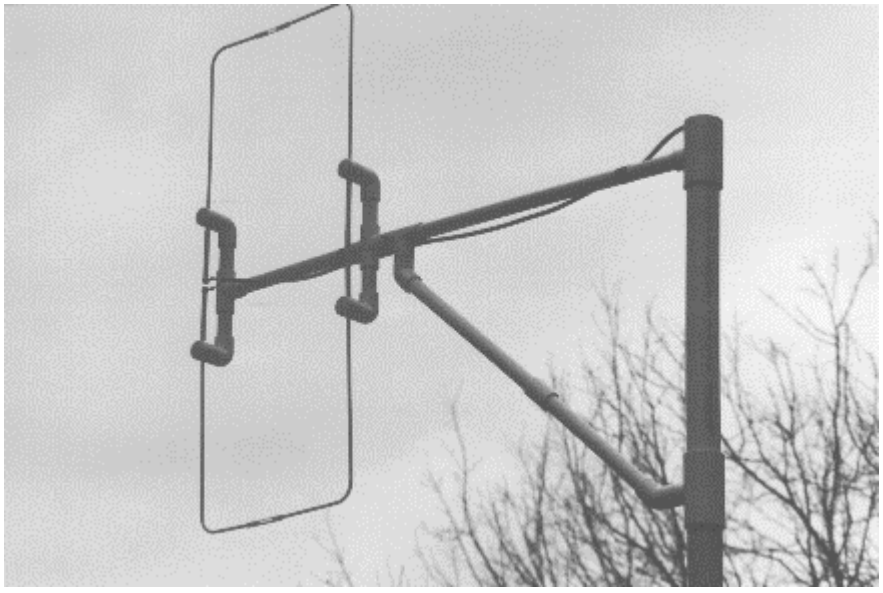
3. Element supports: Technically, booms and masts support antenna elements, but in this category, I include more complex structures. The first three examples happen to be associated with 2-meter antennas.

10 A #12 AWG wire 2-meter half square on a PVC test frame.

The first example, shown in the photograph in **Fig. 10**, is a wire half-square vertically polarized bi-directional antenna. The antenna itself provides a very sharp figure-8 pattern, similar to that of a horizontal dipole, but vertically polarized--and stronger than that of a quad loop. The structure is a custom arrangement of PVC. The horizontal piece is SDR 21, since the only weight it supports is itself. Its function is simply to hold the #12 AWG copper house wire in position. The vertical piece nearest the coax is Schedule 40, since this is the main support. The remaining short pieces are SDR 21. Everything is 1/2" nominal. This fixture is solely for the purpose of testing the antenna design, although it has serve for several years without injury to the antenna.

11 A more complex PVC mounting frame for a 2-element 2-meter half-square beam.

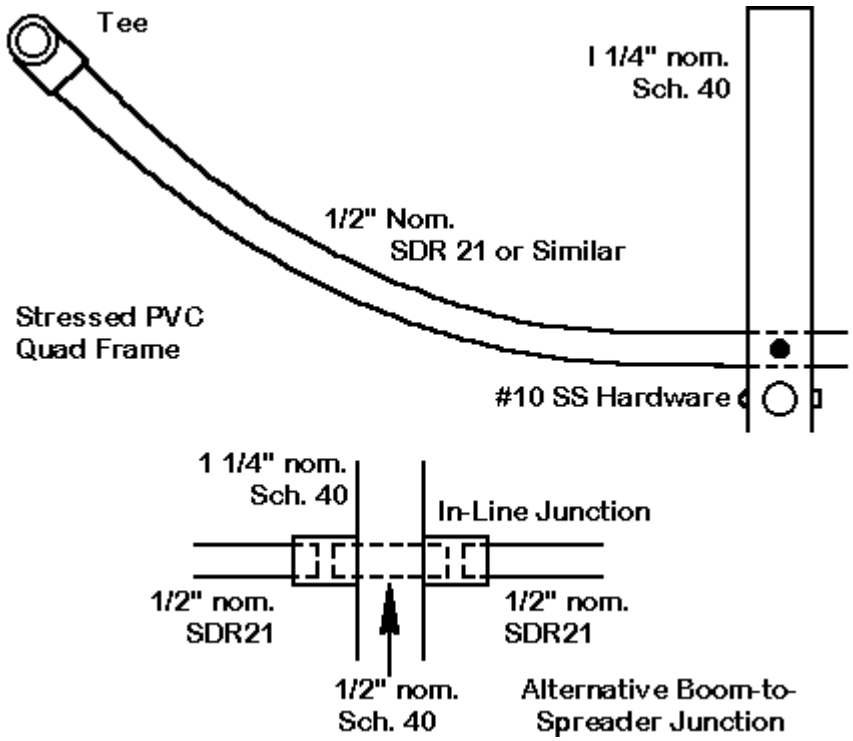
The next photograph (**Fig. 11**) shows a 2-element half-square parasitic beam. The 1/2 nominal pieces are Schedule 40, arranged to provide even alignment for the two element sets. An array of Tees and elbows spaces the elements from the PVC to minimize potential interaction. The horizontal tubing (3/4" diameter) passes through the 1/2" nominal Tees and is fixed in position by single sheet metal screws at each Tee. This support system is designed for a centered support mast.



12 A vertically oriented 2-meter Moxon end-mounted on a braced PVC support.

Similar to the half-square beam mounting is the element support system for the 2-meter Moxon rectangle, shown in the photo (**Fig. 12**) oriented for vertical polarization. A single bolt on the support arm behind the reflector permits me to rotate the antenna to the horizontal position. The unique part of this assembly is the remainder of the support arm, which extends to a mast stub well behind the antenna elements. To brace the support arm, Tees plus Ys are arranged to form a triangular brace. Also evident is a repair in the

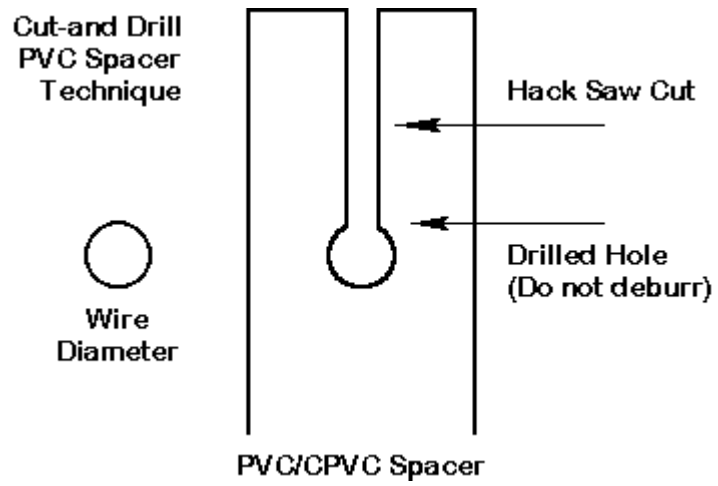
angular tube: I cut the bad portion out and added an in-line junction and the short piece to the Y junction. Once more, everything here is 1/2" nominal.



13 A sketch of a stressed-PVC quad spreader and boom assembly.

For either HF or VHF quad antennas (likely no larger than a 15-meter version), we can use a stressed-PVC spreader and boom structure. A sample is shown in **Fig. 13**. For miniature quads for 10 meters, a single 10' length of 1/2" nominal SDR 21 (or similar thin-wall PVC) can pass through holes in a 1 1/4" nominal Schedule 40 boom. Pin the tubing in place with #10 stainless steel hardware. Offset the two lengths of tubing required to obtain 4 spreaders. Add 1/2" Tee fittings to the ends of the spreaders as a smooth surface for the quad element wires at the corners. Stress the tubing to create a square of the right size for the quad loop. I initially use twine to secure the square and then add the wire. I add bridge wire at each tee, which prevents slippage and a wind-forced reversal of the arms.

If you need longer arms, you can use a short piece of Schedule 40 PVC through the boom holes, with in-line junction glued in place. Then you can make arms up to 10' long in each of the 4 directions. However, there is a limit to the durability of stressed arms based on a. the amount of stress and b. the UV resistance of the tubing used.

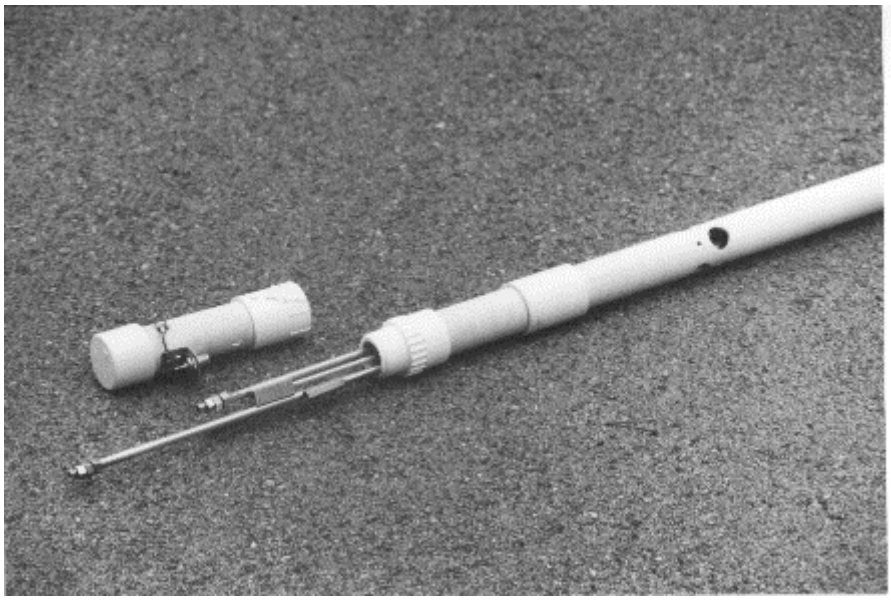


14 A sketch of one way to use PVC spreaders or spacers.

Thin-wall PVC and CPVC are highly usable as wire spacers. Among the possible applications are home-made parallel transmission line, double-wire dipole elements (for wide operating bandwidth), and wire beams for 10 meters and up. **Fig. 14** shows one good technique for preparing the spacers. Hack saw a slot, and then drill a hole as closely as possible to the exact diameter of the wire. I prefer not to deburr the holes. When I press the wire through the slot into the hole, the burrs create a good friction fit that prevents slippage. However, the spacer can still be moved without much force.

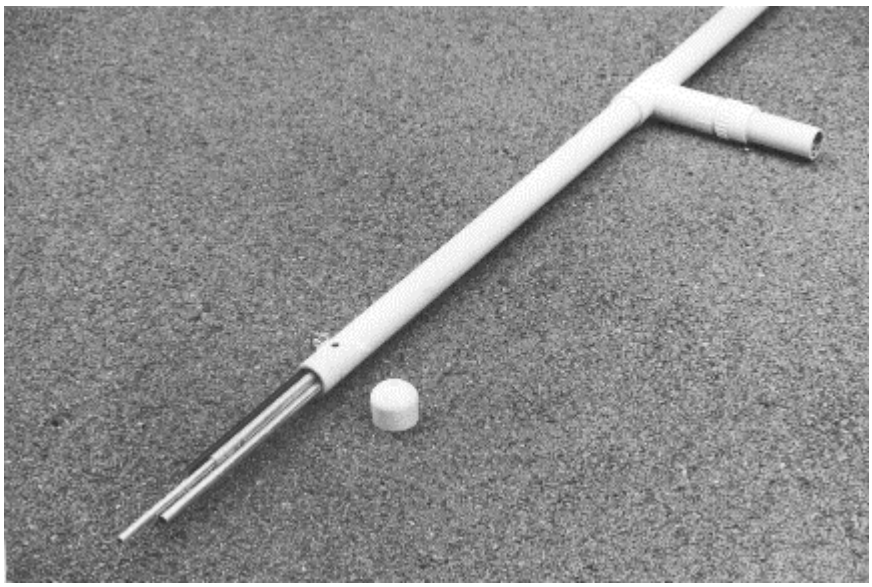
These examples are just five of endless ways to arrange PVC as useful element support structures. Perhaps they are enough to give you a start on your own project.

4. Storage: We may store in a PVC tube, plus caps, almost anything long and thin--like antenna elements. Earlier we saw the dipole in a tube element junction mounted on a mast. In the photo in **Fig. 15**, we can see the rod elements stored inside a capped tube, where the top of the tube holds a female screw junction to mate with the capped element junction piece. The rods are split into two pieces (5/16" inner sections, 3/16" outer sections), joined by a 1/2" x 1/2" x 1 1/4" aluminum block, tapped for the threaded ends of the rods. Disassembled, everything pits inside the tube with room to spare.



15 Dipole elements stored in a PVC tube.

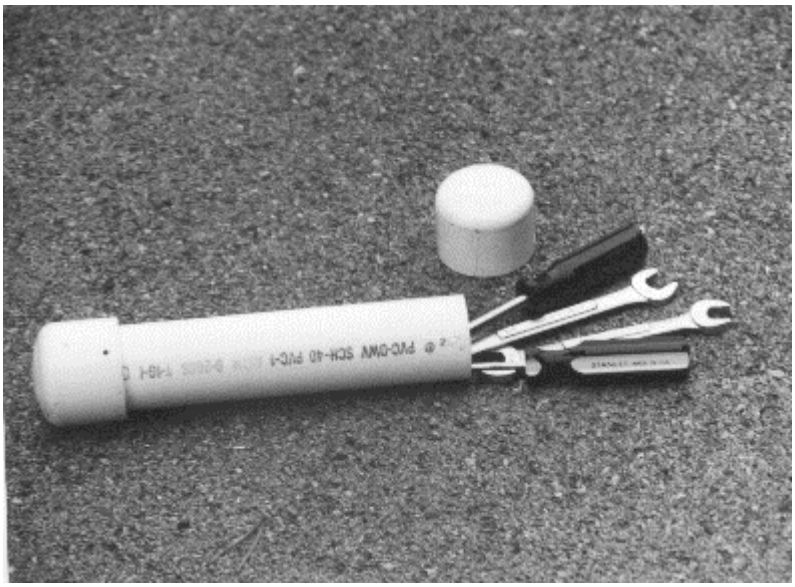
Slightly more complex is the boom of the beam in a boom. The elements are 1/2" and 3/8" diameters tube sections on each side. The tubing nests for each element side. The four tube pairs and the two 2' section of 3/8" fiberglass rod all fit inside the boom itself, a 5' section of 1 1/4" nominal Schedule 40 PVC. As **Fig. 16** shows, the mast stub makes a good grip for carrying the entire antenna to and from the car trunk. Although the assembly may look a bit complex, I have in demonstration talks managed to assemble and disassemble both the dipole and the beam within a 40 minute period, all the while trying to describe the antennas to an audience. On a hilltop, everything goes faster, since I can keep my eyes on the work, only occasionally glancing around for East Tennessee black bears.



16 Aluminum Yagi elements stored inside a PVC boom.

My last photo (**Fig. 17**) is an obvious one. A short length of 1 1/2" nominal tubing, with one end capped permanently by a glue joint, becomes a tool carrier for the two antennas.

Inexpensive screw drivers, nut-drivers, and wrenches, along with a sack of small hardware, easily store in the tube.



17 A simple tool storage tube to carry with portable antennas to hilltops.

These are not by any means the only things we can do with PVC. For example, the four-legged oak support frame, which I used both in my shop and for traveling demonstrations, could also have been made from PVC. I just happen to like wood as well as plastic. In fact, about the only antenna parts that I cannot make from PVC are the conductive elements themselves. At present, the price of aluminum tubing and wire is too low to make PVC elements very practical.

One final note for the ham homestead: If you sand the surface of PVC to give it a "tooth," it will accept a primer for enamel followed by a color coat of good outdoor paint. Hence, it is possible to decorate your yard with your call sign constructed from PVC (including legs to support it). Alternatively, you can create both 2-D and 3-D sculptures from PVC. Combining this idea with others, you can make very non-standard trellises for your decorative vines. You may also construct fences around ground-mounted verticals for safety, using them also as morning glory trellises. With a little ingenuity, a little paint, and a few flowering vines, you can make neighbors forget that 70' tower and maze of wire antennas in the backyard.