# Some Notes on FM BC Antennas Part 3: Some Ideas for Home-Built Beam Antennas

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In the previous episode, we examined a number of practical designs for FM band Yagi antennas. Most of the designs lend themselves to home construction using basic shop tools. In this episode, we shall examine a variety of techniques that you might apply to that construction.

We shall not provide detailed construction notes for each beam, since that would lead to an excessive amount of repetition. Instead, we shall look at general construction techniques that apply to some or all of the antennas. Indeed, for every technique, there are alternatives, and we shall look at a few options that you may have for any given stage in the building process. You may know a number of techniques that I do not.

The process of building your own antenna involves the creative application of your own special skills, new skills that you may wish to acquire, and the adaptation of materials that are available to you. One key to the process is understanding the electrical requirements of the antenna under construction and making sure that you honor those. A second key--especially as you build for the VHF region of the spectrum--is being as careful and precise as you can. The last key is making up your mind to give the task a go and then following up with patient, careful work.

With these preliminaries under our belts, let's begin the process.

**Elements and Booms**

All but one of the Yagi designs calls for the use of 0.25" aluminum rod as the element material. Along the way, we noted that the performance of a Yagi depends upon three interlocking factors: the element length, the element placement, and the element diameter. Changing any one of these factors will alter the performance of the antenna design--or call for a redesign to account for the change. Since it is not possible for me to redesign the Yagis to suit every possible combination of materials that a builder may have, the safest path for both you and me is for me to recommend that you not change the element diameter recommended for any of the designs.

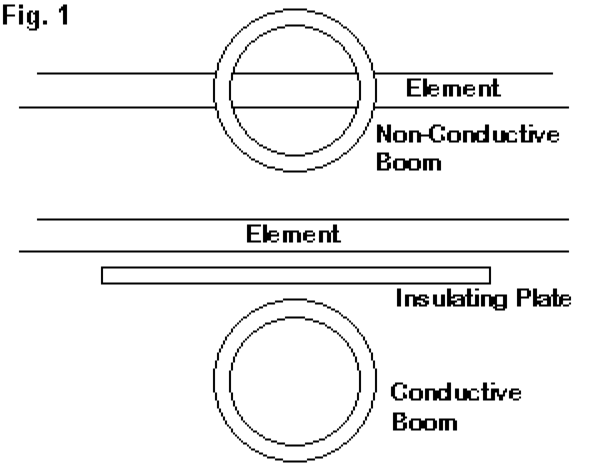
Likewise, do not arbitrarily change the length or placement of any of the elements. (Later in these notes, we shall discuss one change that you can make.) When you cut the elements, try to be precise to 1/16" or better. The most common tool used to cut aluminum rod is the hack saw. Cut the element about 1/16" long and sand the ends down. You will both clean up any cutting burrs and refine the length in the process. Although you can use a file for the task, I prefer sandpaper. A small bench-top disk sander with medium aluminum oxide grit (100 to 150) is ideal. You can safely round the cut edge a bit for ease of handling without altering the dimension.

If you opt to try the wide-band design that uses 3/4" diameter tubing, you may wish to use a pipe cutter to establish the element length. The pipe cutter makes a clean line and does not tend to cut at an angle, as is often the case with my hack-saw cuts. You can even up the ends with the disk sander after doing an initial deburring of both the inside and the outside of the cut end with a sharp knife.

Aluminum rod and tubing in the sizes that these designs use may be available at home centers. However, I prefer to use antenna-grade aluminum that I purchase from mail order houses, such as Texas Towers. They sell 6063-T832 tubing in 6' lengths (for UPS shipping), which is deal for FM band projects. Their rod material is 6061-T6. The elements in our Yagis ranges from just about 4' to just under 6'. The advantage of using rods and tubes from such sources s that the electrical and mechanical properties are well known. For example, in a project that requires slipping one size tube inside another larger size, the 0.55" wall thickness allows clearance but also a close fit. Home center tubing tends to have thinner walls, making a close fit harder to achieve. As well, these materials have known strengths, and so you can estimate how well your antenna will stand up to your weather.

Next comes the boom that supports the elements. Essentially, within the limits of these projects, you have two choices, illustrated in **Fig. 1**.

Fig. 1




Alternative Element Mounting Systems for Conductive and Non-Conductive Booms

If you use a non-conductive boom, you may drill it so that the elements pass through its center line. If you plan to use a conductive boom, such as aluminum tubing, then you should plan on adding insulating plates with the boom on one side and the elements on the other.

It is possible to use through-boom element mounting with a metallic boom and still effect insulation of the elements with non-conductive bushings. However, the close proximity of the element to the metallic boom will require adjustment to the element lengths. The calculation for adjusting the element lengths is contained in an article at this site (../scales.html). However, we shall not cover those adjustments in these notes. Instead, let's focus on your two main options.

For booms up to about 8' in length, Schedule 40 PVC is a good material to use for a boom. Since the boom will live in the weather and sunshine, be alert to an interesting fact about the standard white PVC. In some parts of the country, such as the southeastern U.S., the white plumbing PVC is quite well UV protected. I have some ten-year-old pieces in daily sunshine that are just now becoming brittle enough that I would not try to cut them with a chop saw. However, in other parts of the country, white PVC appears to have less UV protection and may last only a year or two in the sun. If your local white PVC is not UV protected, consider using the gray material in the electrical conduit section of the home center.

PVC has an entire family of junctions, couplings, and adapters. The greatest number of these are available in plumbing white. Even where there are similar white and gray couplings, they may not be identical in both inner and outer dimensions. It pays to wander the aisles of a home center getting a good feel for what is available and adaptable to service.

Remember that Schedule 40 PVC is sized to piping standards, not tubing standards. If you order 0.75" aluminum tubing, that is the outer diameter. If you pick up a piece of similarly sized PVC tubing, you will find that it is listed as 3/4" nominal, meaning that the inner diameter is at least 3/4". The outer diameter will be just over 1". Likewise, 1" nominal PVC has an outer diameter closer to (but certainly not exactly) 1-1/4". For the FM band antennas, I recommend either 3/4" or 1" nominal PVC for the boom.

The reason that I do not recommend PVC for the 14' wide-band Yagi is that PVC is heavy and tends to sag in long unsupported lengths. For long-boom Yagis, aluminum tubing is standard. To make a long boom, you can use 6' lengths by combining two sizes of 0.55" wall thickness tubing. Use either a combination of 1.25" and 1.125" tubes or a combination of 1.125" and 1" tubes. For a 14' boom, we shall need 2 6' lengths of each, plus 2' or so more. (Remember my recommendation that you make the support boom a bit longer--say 6"--than the element boom length listed in the dimension charts.) Simply stagger the junctions of the two tubing sizes. You can lock the tubes together with stainless steel sheet metal screws (stainless steel, of course). However, be sure to pre-plan the screw placement so that these fasteners do not interfere with any of the element assemblies.

The conductive boom system requires one more basic material: the plate. I tend to prefer polycarbonate (trade name Lexan), which is available from numerous mail sources, such as McMasters-Carr. It is available in 1' x 2' sheets in various thicknesses. 1/4" thick material is more than adequate for element-to-boom plates, but you may want a sheet of 3/8" thick material if you wish to make an insulated boom-to-mast mounting plate.

**Element Mounting**

Let's return to our PVC boom and prepare to mount elements through it. First, we have to drill holes in the boom for the elements. Let's initially drill for only the parasitic elements, that is, every element except the driver.

It is imperative that we keep the elements well aligned. Hence, it pays to do two things before drilling. One step is to obtain some kind of drill press. If you do not otherwise need a floor or bench mounted drill press, purchase one of the fixtures that allows you to mount your electrical drill in it. It will work well for this purpose if you also take the second step. Create from scraps of lumber a jig to hold the boom. You need to be able to lock it in two dimensions. The tubing should not be able to rotate between drillings, and the drill bit should come down for each hole at the exact center line of the tube.

Although we shall not perform this next action until we finish all of the work on the boom, let's deal with the challenge of holding the element in place once we push it through the boom hole.

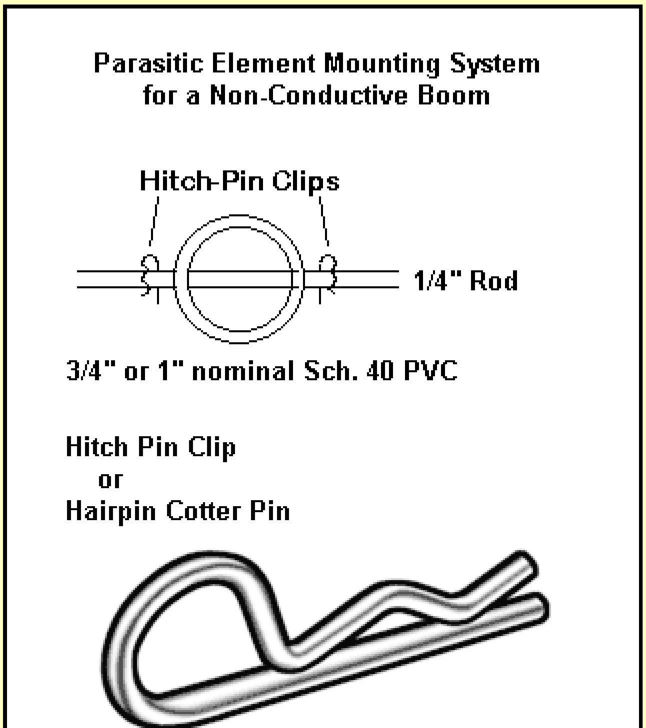


Fig. 2

**Fig. 2** shows one way to lock the parasitic elements in place. Obtain small hitch-pin clips from your home center, hardware outlet, or mail-order source. Be sure that the 1/4" rod size is within the clip range. Pre-fit the rod to the boom and mark point on the rod where the rod meets the PVC wall. Allow about 1/32" on each side for the thickness of the pin. With a jeweler's file, create a small flat spot at this point so that your drill bit will not slip. Drill a hole that just passes the hitch-pin clip. When you are ready to assemble the beam, you can slip in the tube and add the clips. Their tiny metal mass will not affect the element's performance. However, use stainless steel clips, not the plated ones that will eventually rust when subjected to continuous weathering.

The driver element requires special treatment, since we need to split it into two halves and make a gap between the halves for electrical connections. Let's consider two systems.

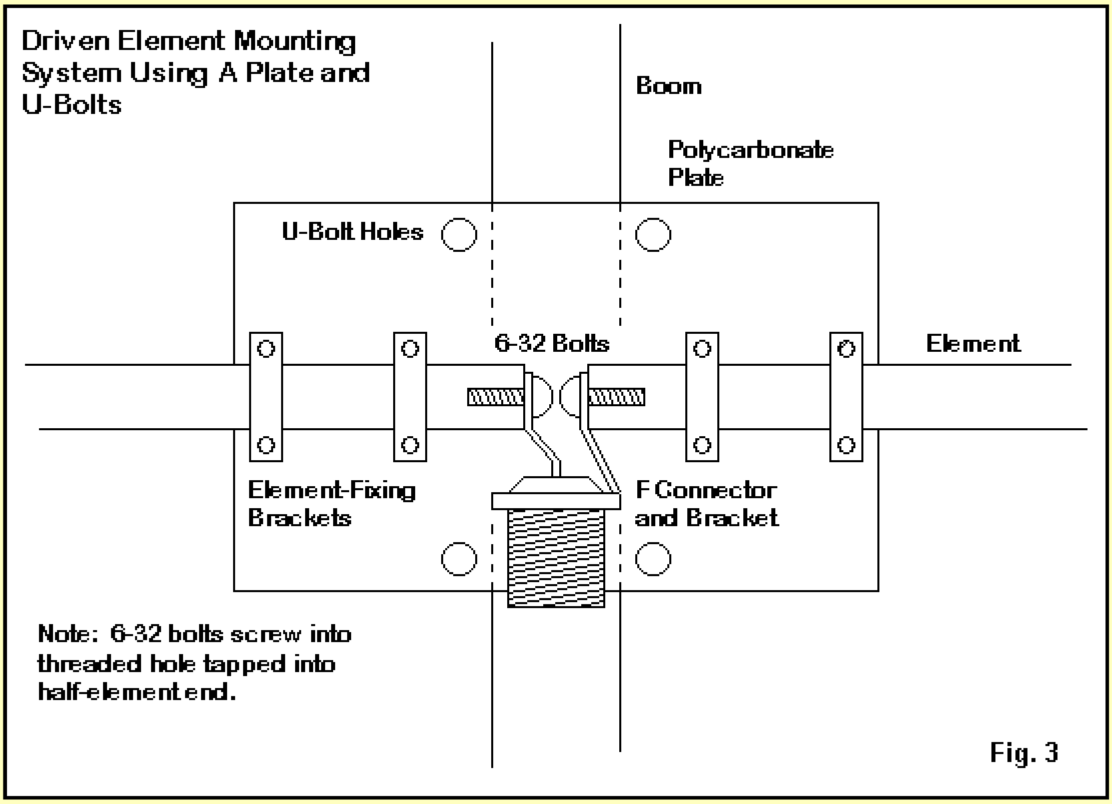


Fig. 3

**Fig. 3** shows one system. It consists of an insulating polycarbonate plate with the two element halves mounted with brackets. Because tiny u-bolts may not be easy to obtain for the 1/4" diameter elements, you may have to make up your own brackets out of strips of aluminum. Examine the brackets used to fasten electrical conduit to walls, and copy the construction in miniature. For fasteners, use 6-32 stainless steel nuts, bolts, and lock-washers.

Alignment will be important so that the element is parallel with the others. (The half-inch or so distance out of plane with the other elements will make no difference at all.) One technique that I have used is to rout a shallow groove in the plate so that the element is self-aligning. Do not rout the line so deeply that it weakens the plate.

To make connections, simplicity is usually best. One simple system is to drill a hole in the gap end of each half elements--about 1/2" deep. Tap this hole for 6-32 hardware. Add a solder lug (and lock-washer, if not part of the solder lug) for making connections between the half element and the coaxial cable connector. As in every construction step, use stainless steel hardware (except for solder lugs).

You can mount the cable connector to the boom by using 1" aluminum L-stock to make a bracket. 1/16" thick material works well. I tend to do my drilling with a piece of stock larger than I need. Then I cut it to size and finally shape the edges to suit the job.

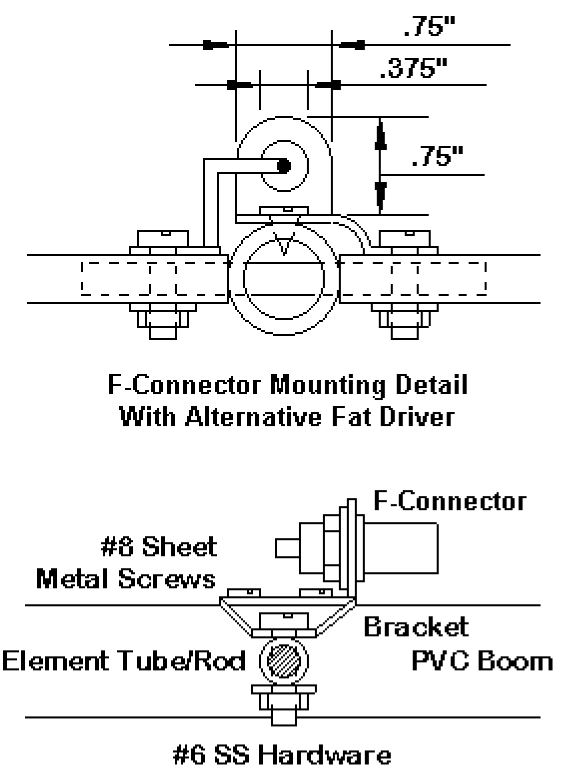



Fig. 4

**Fig. 4** shows an alternative driven element mounting system that does away with the need for a plate. However, it requires that we make the driver from 0.5" diameter aluminum tubing. At the driver position on the boom, we drill a 3/8" hole and insert a 5" to 6" length of 3/8" diameter fiberglass or similar rod. We can glue the rod in place. Then we slip the element halves over the rod. When we make connections to the tube halves, we lock them into position over the rod.

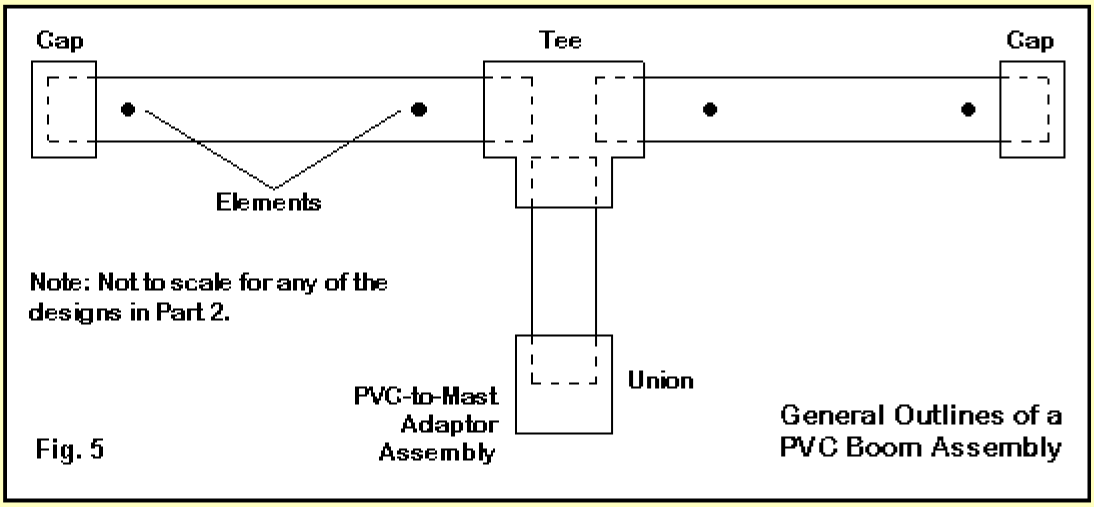
We have selected these rod and tube sizes because they are large enough to accept 6-32 stainless steel bolts without weakening them. Smaller diameter materials will not leave enough rod material after drilling for the hardware. Smaller hardware is available, although 2-56 hardware may not be readily available in stainless steel, and 2-56 solder lugs tend to be quite tiny.

The driver element has become thicker, so its tip-to-tip dimension must be shorter. If you opt for this system, then for each of the narrow-band Yagis, shorten the driver's overall length by 1%. (The actual figure is closer to 0.8%, but that difference will make no operational difference in antenna performance. Note that this adjustment applies only to the driver and not to the parasitic elements. If you wish to use fatter elements, then each element will have its own unique length, as calculated by a means described in the earlier noted article on adjusting VHF beam dimensions and through-boom mounting of elements.)

The sketch also shows a connector mounting bracket that I shaped to the boom. It connects to the shell of the connector and to the element without needing any additional solder connection. Only the center pin needs to use a soldered wire that runs from the connector to the element half.

You are now ready to assemble the beam. Simply put all of the pieces together as indicated and you are almost ready for mast mounting. However, our first mounting will be to test the antenna. Once we are satisfied that all is well for the long term, coat the driven element connections with Plasti-Dip or Brushable Electrical Tape (trade names for insulating protective coatings). Use 2 or 3 thin coatings to be sure that weather cannot penetrate to the connections, but avoid excessive amounts that will detract from the appearance of the finished product.

To mount the beam to a mast, you may use a standard mounting plate or you may take advantage of the collection of PVC junctions. See **Fig. 5** for the basic idea.




You can estimate the center of weight for the 6-element Yagi. For the 3- and 4-element models, the weight is not critical, so you can place the center Tee fitting anywhere close to the center point. If you use this system, install the Tee fitting prior to drilling the element holes.

From the Tee, you can use a series of threaded adapters to change the size of the mast stub. PVC has a complete array of adapters, some that are combinations of male and female threaded fitting for changing size, and some that have a threaded end and a cemented end (for the final pipe size). You may. for example, increase the pipe size to 1-14" nominal, which fits loosely over standard TV mast. A bolt through both the pipe and mast locks the two together.

There are also cross fittings, some of which have one size pipe in one direction and a different size pipe in the other. You can likely find one that will fit the boom horizontally while sliding over the vertical mast.

**The Wide-Band Yagi**

In the process of exploring construction options for the smaller Yagis, we have encountered virtually every idea that we need in order to make the wide-band Yagi, with its 0.75" diameter tubing elements.

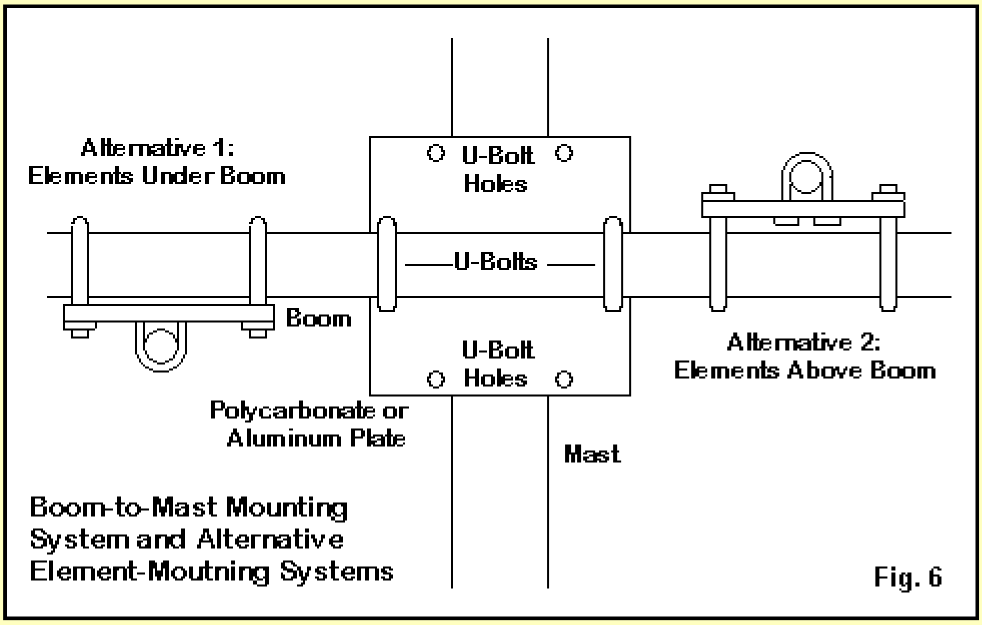



**Fig. 6** reveals that the task is largely a matter of finding enough polycarbonate plate and u-bolts for the job. The element, boom, and mast sizes are generally amenable to the use of marine (stainless steel) u-bolts. However, for extra security, companies like DX Engineering make such U-bolts with saddles to support the tubes and prevent crushing.

Since the wide-band Yagi's boom will be conductive, you may use an aluminum plate for the boom-to-mast fixture. 1/4" thick aluminum stock is available, but may be more difficult to cut than polycarbonate.

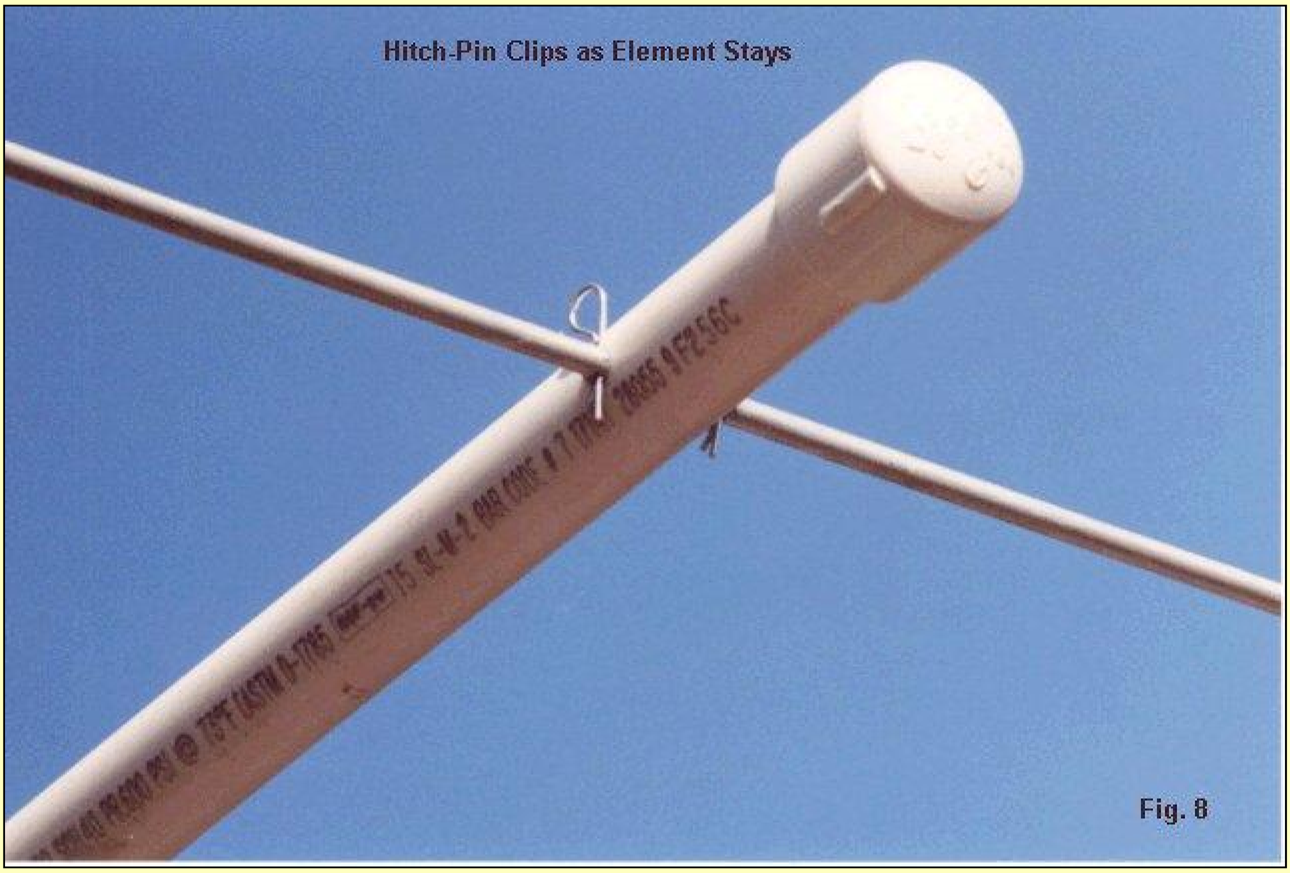
The driver element will use a mixture of techniques. It will mount on a plate. If you insert a short length of fiberglass rod (0.625" diameter) or a length of CPVC (1/2" nominal will just fit inside 3/4" tubing), you need only have the outer u-bolts, and the element will stay aligned. Make connections to the connector on its bracket with 6-32 stainless steel hardware and soldering lugs. As always, keep any wire leads as short as feasible. Coat the final connections after testing.

The figure also gives you 2 options for element placement: above or below the boom. Letting the elements hang below the boom tends to make element alignment more durable when using u-bolts. Gravity tends to aid the maintenance of correct element positioning.

**A Sample PVC Yagi**

Let's examine briefly a test Yagi using a PVC boom. The photo in **Fig. 7** shows the overall structure of the 6-element antenna that is a scaled version of the design in Part 2.

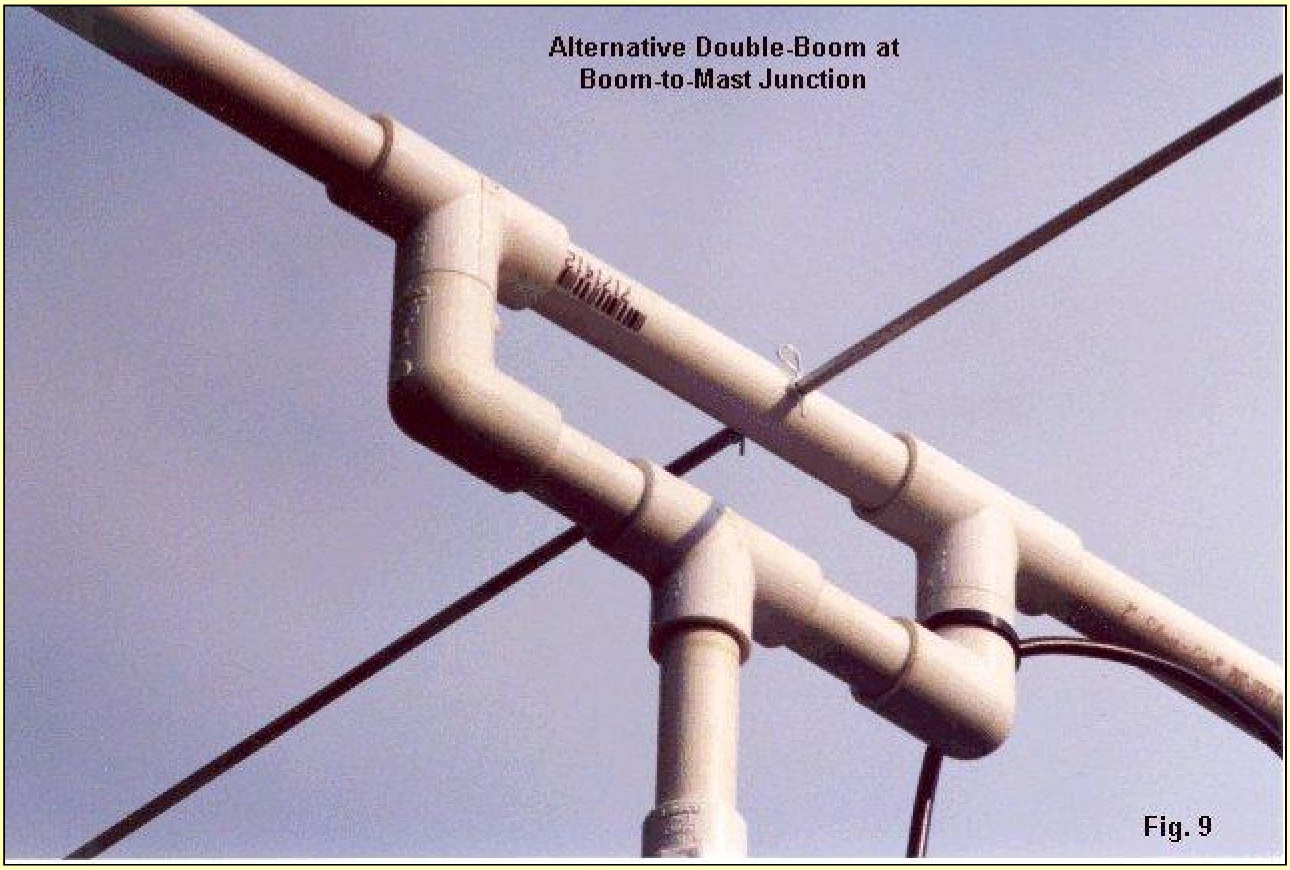

Besides counting elements, there are two features worth noting in this photo. First, I have capped the boom ends to keep insects and dirt from finding a home inside the boom. Second, note the collection of adapters running from the mast stub on the boom and the larger PVC used as a test mast.



Hitch-Pin Clips as Element Stays

Fig. 8

**Fig. 8** gives us a closer view of the unique double-boom section that I designed into the assembly--and a clue to why it is there. If you make a mental line from the element on the main boom, it runs through the Tee connector on the lower boom section. To avoid having to run the element through a Tee fitting, I preplanned the assembly to add the lower secondary boom section. In fact, I constructed the entire boom before drilling any holes in order to be certain that everything was straight and true. A side benefit of the secondary boom section is that it shortens the lengths of PVC boom extending to the end caps. The shorter the PVC run, the less the sag.



Alternative Double-Boom at Boom-to-Mast Junction

Fig. 9

A close-up of one boom end appears in **Fig. 9**. It shows the boom cap and the hitch-pin clips securing the element in place. Some builders have used compression C or E clips, but I have found the hitch-pin clip to be more secure in the long haul.

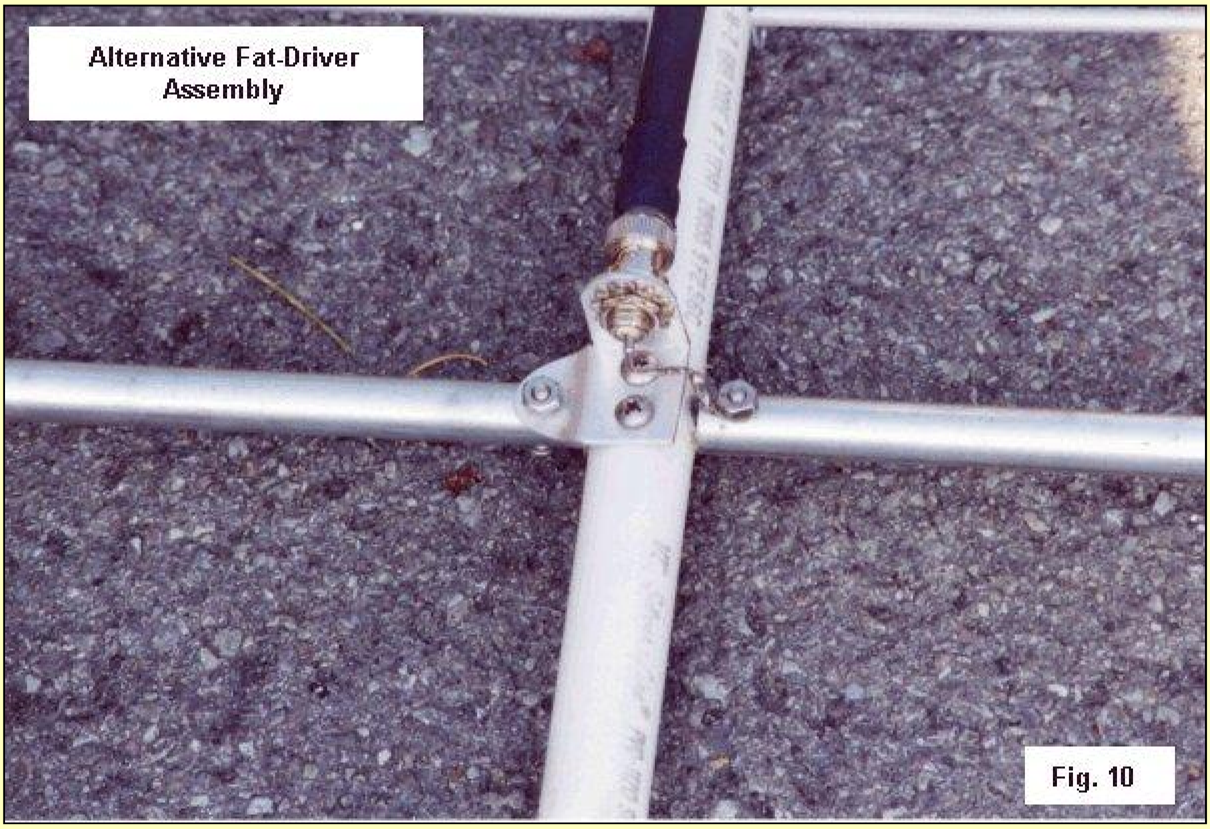


Fig. 10

The final photo--**Fig. 10**--is a close-up of the fat-driver and connector assembly. The connector in the photo is a BNC to suit the cables to my test equipment. However, similar brackets would suit F connectors, which tend to be standard in TV applications since the advent of cable. Incidentally, do not use slip-on F connectors. Instead, use screw-on versions to ensure a long-term connection. After all testing, coat the junction for weather protection--or use one of the newer connectors that are weather secure. However, for the chassis-mounted connector on the bracket, coat the exposed connections.

Part of my object in developing the antenna in the photos was to minimize the number of nuts and bolts required by the antenna. Besides non- critical hitch-pin clips, the antenna needs only two sets of 6-32 hardware for the driver junctions at the gap and two #8 sheet metal screws to fasten the connector bracket to the boom. Whenever you use a sheet metal screw in PVC, make the pilot hole a drill-bit size smaller than you would for metal. This practice allows the sheet metal screw to get a good secure bite into the plastic material. Of course, even the sheet metal screws are stainless steel.

Stainless steel hardware serves two purposes. It does not rust. In addition, it avoids reactive bi-metallic contact between two metals. Bi-metallic contact that permits electrolysis eventually weakens the connection mechanically and tends to add electrical resistance to the contact.

There are enough construction ideas and principles in these notes to get you started on your own antenna building project. However, do not think that these notes are the final word on home antenna building. Use and adapt your own shop equipment and skills to the task. You are likely to come up with even better, more secure, and simpler techniques. However, always keep in mind the electrical requirements of the antenna itself.

With these notes as complete as I can make them, we can turn to our first alternative to the Yagi: the log periodic dipole array (LPDA). However, when we cover the construction aspects of this antenna, many of these notes will be very relevant to that antenna as well.