Notes on Home-Built Antenna Hardware

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In the course of writing the many items at this site, I have scattered a number of notes on antenna materials or hardware. As the site has grown, the odds of a reader encountering a relevant note have decreased accordingly. Therefore, this note attempts to coalesce a number of thoughts on antenna hardware in one place.

The notes represent a set of practices that I prefer. The collection is not the only way to do things, but it is one fairly good way among the many acceptable practices. Nevertheless, I recommend that you examine various antenna handbooks for alternatives. We all have different skills and our access to materials may vary. The more techniques that you have at your disposal, the easier it will become to find the ones that fit your circumstances.

I have divided the material into two major divisions that cover hardware and techniques: beam antennas and wire antennas. The notes focus on HF antennas in the main.

Beam Antenna Hardware

My preferences for beam construction all focus upon one word: quality. Quality construction is a synonym for durability, that is, the ability of the beam antenna to perform for a long period with all of the capabilities it had when you first put it in place. Quality beam construction breaks down into three main materials: stainless steel, aluminum, and polycarbonate.

Stainless Steel

I prefer to use only one material for all antenna hardware: stainless steel. Not many years ago, we had to use mail order or on-line sources for stainless steel nuts, bolts, and washers. However, these items are now regular stock in many home centers. The reason why I prefer stainless steel is simple. Virtually all beam antennas bring together at least two materials: aluminum and copper. Dissimilar materials are subject to electrolysis, the corrosion of materials due to a difference in the atomic electrical potential of each material. Copper and aluminum are both conductors, but we cannot durably join the two at a connection point. When some home builders resorted to cheaper aluminum AC wire, they had to find connectors that would prevent electrolysis between the aluminum wire and the brass (mostly copper) screws at the terminals. Only power companies use aluminum wire these days and homes have returned to an all-copper status.

The rate of corrosive effects between dissimilar metals depends on their "nobility." The more distant the metals on the chart (see **Table 1**), the greater the potential between them, even in the most weather-protected conditions. As the table notes, a difference of only +/-0.3 volts between the atomic potential of two metals at a junction indicates the strong possibility of significant corrosion at the junction. Note how far apart that aluminum and copper fall on the table.

Atomic Potential of Various Metals that Might Come into Contact with Each Other								Potentials in volts				Table 1
Metal	Magnesium	Aluminum	Zinc	Iron	Cadmium	Nickel	Tin	Lead	Copper	Silver	Palladium	Gold
Magnesium	0.00	-0.71	-1.61	-1.93	-1.97	-2.12	-2.23	-2.24	-2.71	-3.17	-3.36	-3.87
Aluminum	0.71	0.00	-0.90	-1.22	-1.26	-1.41	-1.52	-1.53	-2.00	-2.46	-2.65	-3.16
Zinc	1.61	0.90	0.00	-0.32	-0.36	-0.51	-0.62	-0.63	-1.10	-1.56	-1.75	-2.26
Iron	1.93	1.22	0.32	0.00	-0.04	-0.19	-0.30	-0.31	-0.78	-1.24	-1.43	-1.94
Cadmium	1.97	1.26	0.36	0.04	0.00	-0.15	-0.26	-0.27	-0.74	-1.20	-1.39	-1.90
Nickel	2.12	1.41	0.51	0.19	0.15	0.00	-0.11	-0.12	-0.59	-1.05	-1.24	-1.75
Tin	2.23	1.52	0.62	0.30	0.26	0.11	0.00	-0.01	-0.48	-0.94	-1.13	-1.64
Lead	2.24	1.53	0.63	0.31	0.27	0.12	0.01	0.00	-0.47	-0.93	-1.12	-1.63
Copper	2.71	2.00	1.10	0.78	0.74	0.59	0.48	0.47	0.00	-0.46	-0.65	-1.16
Silver	3.17	2.46	1.56	1.24	1.20	1.05	0.94	0.93	0.46	0.00	-0.19	-0.70
Palladium	3.36	2.65	1.75	1.43	1.39	1.24	1.13	1.12	0.65	0.19	0.00	-0.51
Gold	3.87	3.16	2.26	1.94	1.90	1.75	1.64	1.63	1.16	0.70	0.51	0.00
Notes:	1. Accelerated corrosion can occur between unprotected joints if the algebraic difference in atomic potential is greater than +/-0.3 volts.											
	2. Metals are considered more noble as they move from Magnesium to Gold.											
	3. For any two metals in contact, a less noble metal is considered more "anodic" and will give up metal in a contact joint.											
	4. Adapted from page 18 of *The Grounds for Lightning and EMP Protection*, 2nd Edition, PolyPhaser Corporation.											

Stainless steel is generally inert to electrolysis. Hence, it makes the best simple buffer between different metals that might show significant corrosive effects. **Fig. 1** shows a sample connection at possibly the feedpoint of a beam's driven element. Note that the system uses not only a stainless nut and bolt, but also stainless washers. Hence, the copper wire is isolated physically but not electrically from the aluminum tube.

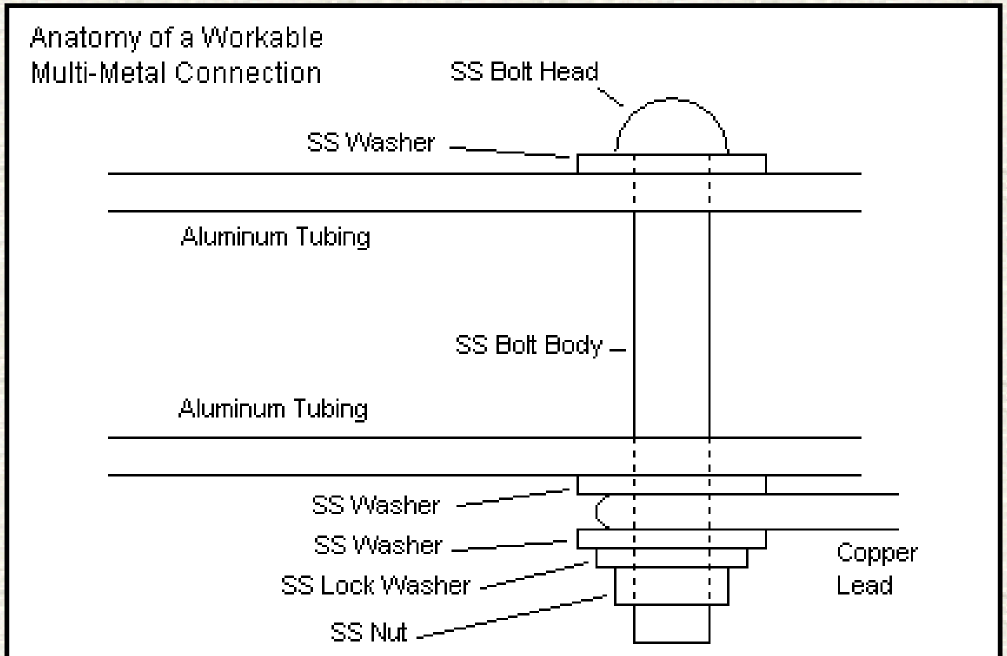


Fig. 1

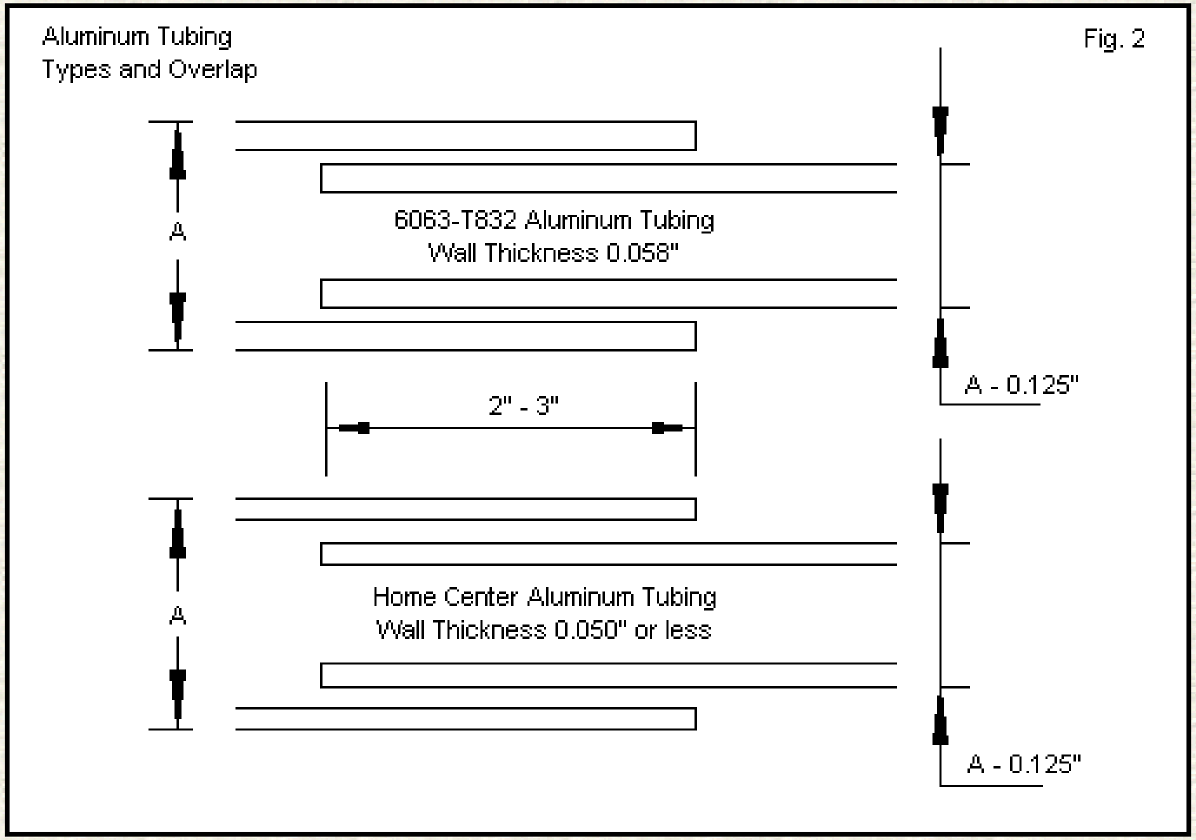
Two washers deserve special mention. I place a washer under the bolt head to spread the force that the head exerts on the softer aluminum tube. Excess tightening will not result in the bolt head widening the hole in the tubing. In most cases, I add a fiberglass rod within the rube to strengthen the assembly. If I butt-join tubes, I add an inner tube for the same reason. The other notable washer occurs next to the nut. I use a stainless lock washer to ensure that the assembly does not come apart after a season of flexing in the weather.

Aluminum

The subject of aluminum bothers many a newer antenna builder because of its cost if we buy it new from reputable sources. Due to cost, many builders resort to wire beams, while others build only antennas for which they can find used TV antenna elements. At one time, home centers carried a large and varied stock of aluminum tubing, but in recent years, the centers have shifted their stocking philosophies from "do-it-yourself-in-your-own way" to "do-it-as-pre-packaged." Some antenna builders have shifted to the use of L-stock and square stock.

First, round tubing is the best material available for HF antenna elements, since it tends to slip the wind best. Flat surfaces tend to increase wind resistance. Second, I do not recommend even home-center tubing for antennas designed to withstand many seasons of rough weather. The tubing available in home centers is of dubious lineage, and its strength data is often wholly unavailable. Most of all, I do NOT recommend the use of aluminum conduit for antenna elements. Conduit is a form of softer pipe. It not only weighs more than tubing, it also bends permanently under loads.

The best material for U.S. antenna builders is 6063-T832 aluminum tubing, available from various outlets. The tubing is strong, and the most common wall thickness for the home antenna builder is 0.058". It is also available in outer diameter increments of 1/8" (0.125"). If we used a wall thickness of 0.0625"--that is, 1/2 the increment between tubing sizes--we would ideally have a perfect fit from one size to the next. However, this approach fails to recognize that even computer-controlled industrial processes have allowances. Hence, the 0.058" wall thickness allows the closest practical size for nesting one tube inside the next larger size, as suggested in **Fig. 2**.



The lower portion of the figure suggests the use of home-center tubing, which usually has a wall thickness of 0.050" or less. Note the larger spacing between the nested segments. The larger spacing yields more wiggle room, which calls for special measures to ensure a tight mechanical bond between element sections. The upper portion of the sketch with the standard 6063-T832 tubing would allow the use of a simple pair of sheet metal screws to bond the sections--stainless steel sheet metal screws, of course.

The sketch also specifies an overlap of 2" to 3" at the junction. There are special cases in which it is wise to double tubing. For example, the centermost part of a 20-meter beam element might use about 3' of 1.25" stock. The next exposed length might be only 24" or so, but the 1.125" tubing would go all the way to the element center, giving the middle of the element extra strength to bear higher wind loads. Where we do not need doubling strength, 2" to 3" of overlap is sufficient to provide a strong connection without adding unnecessary weight to the element.

Some antenna makers prefer to use thinner-wall tubing to create equally strong but lighter and more flexible element assemblies. Other makers use swaging techniques to decrease the element diameter by either 1.5 or 2 steps, relative to our standard 1/8" increments. In most cases, the home builder does not have access to the necessary equipment to handle such techniques, and the lighter tubing in the requisite aluminum type may not be readily accessible. Hence, the use of the tubing that we have noted is almost the *de facto* American standard. In contrast, European antenna makers tend to prefer heavier tubing (in metric increments, of course). Their antennas tend to bear larger ice and snow loads, but may require a larger rotator to turn effectively.

Polycarbonate

Since I use antenna modeling software to design antennas that I build, I always plan on insulating and isolating the elements from the supporting boom. NEC and MININEC calculate only axial currents along an element and hence cannot show the effects of the boom, were we to make a direct connection. All beam designs that appear at this site either use non-conductive booms or use plates to insulate and isolate the elements from the boom.

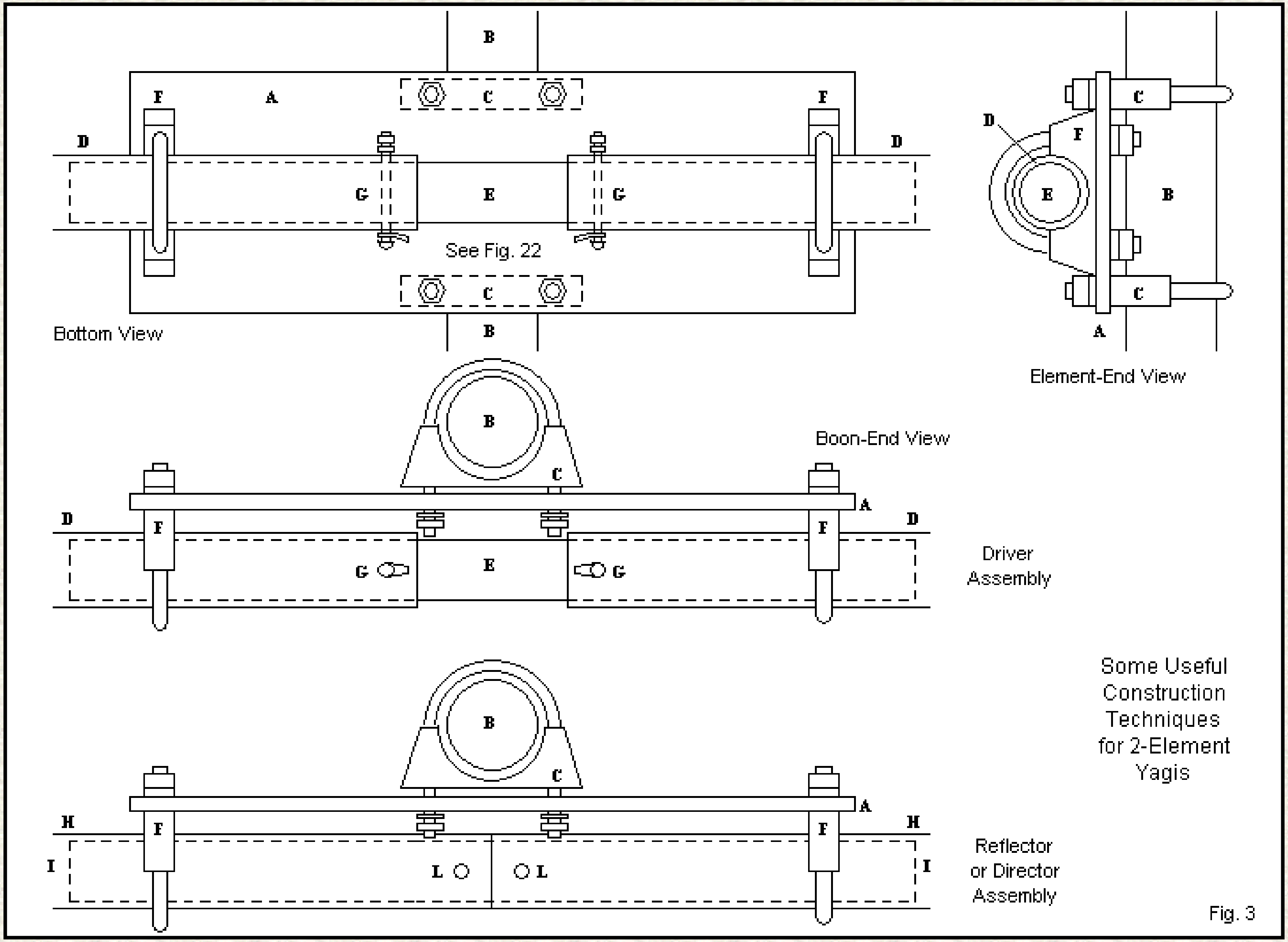
At HF, the best plate material in my experience is polycarbonate. Lexan is a GE trademark and trade name for the material. Do not confuse the material with acrylic materials that ball up under a saw blade. As well, polycarbonate differs from Plexiglas, another trademarked material. All of these materials are related chemically, but we can obtain "true" polycarbonate from on-line sources in convenient size sheets that we can then saw and drill with woodworking tools. Simply be certain that the polycarbonate is UV protected. The plate size will vary with the amateur band, which generally determines element size and weight. ¼" thick material generally satisfies most upper HF requirements. Although polycarbonate is satisfactory well into the lower UHF range, many VHF and UHF beam builders prefer Delrin and other later materials for insulating plates and shapes.

To use polycarbonate plates effectively requires that we design an assembly that makes best use of their strengths. The assembly requires a variety of parts. **Table 2** provides a key to the parts that appear in the sketches in **Fig. 3** and **Fig. 4**.

Table 2. Key to elements in the constructions sketches (See Fig. 3 and Fig. 4)

A	Polycarbonate element-to-boom mounting plate
B	Boom
C	Boom stainless-steel U-bolts and saddles
D	Driven element tube
E	Driven element gap insulating rod or tube
F	Element stainless-steel U-bolts and saddles
G	Stainless-steel nuts/bolts/washers/soldering lugs
H	Reflector or director element tubes
I	Inner linking conductive tube
J	L-stock coax connector mounting plate
K	Through-chassis coax connector
L	Stainless-steel sheet-metal screws

The plate itself is oblong, extending 6 to 12 inches along the element axis and perhaps 4 to 6 inches along the boom axis. The larger numbers, of course, apply to bands like 20 and 17, while the smaller dimensions are for 12 and 10 meters. As suggested by **Fig. 3**, the use of a longer dimension along the element axis places the element U-bolts at a larger distance to allow for assembly work at the element center.



Stainless steel U-bolts attach the element to one side of the plate, while similar U-bolts clamp the plate to the boom on the other side. I prefer the type of U-bolt that comes with a cast saddle over other types. The absence of any saddle tends to allow element slippage over time. Muffler-clamp type saddles contact the element in two lines, which can more easily deform the element tube than the solid cast saddle. In most cases, the boom U-bolts will be larger than the element U-bolts, since booms may range from about 1.25" for lighter beams to perhaps 2" for longer ones. Boom materials can be either 6063-T832 or 6061-T6. For anything heavier than a 2-element beam, it is useful to use thicker tube walls, perhaps 0.125". For smaller beams, you can nest 1.125" tubing with 0.058" walls inside 1.25" tubing with the same wall thickness. If you need a longer boom than the stock available, you may stagger the junctions of the inner and outer tubes to achieve a stronger boom with a uniform diameter.

For parasitic elements, you may use a single center element section or you may link two sections with an inner strengthening tube. Even where you do not need doubling, the inner tube should extend at least to the edges of the polycarbonate plate so that the U-bolts go around a double thickness of tubing to help avoid crushing. The driver element replaces the linking tube with a non-conductive rod or tube, such as fiberglass. The rod helps align the element and provides for the required driven element gap. Note that the gap in any antenna is a part of the total element length. It is NOT an an addition to the length. The gap size is not critical, since the leads from either side of the gap to the feedline connector make up any missing length. Essentially, the final gap size is the spacing between the conductors in the feedline.

All hardware (except for U-bolt cast saddles) is stainless steel. **Fig. 4** shows an exception to this rule. The support for the coax connector consists of a short length of 1" by 1" by 1/16" thick L-stock. The length is just enough to serve as a U-bolt keeper bar. At the center, a 5/8" hole allows you to mount a through-chassis coax UHF connector. Leads to the element are short and direct. Use a "liquid" (plastic) electrical tape product to seal the coax connector rear end--and the coax junction once you install the feedline.

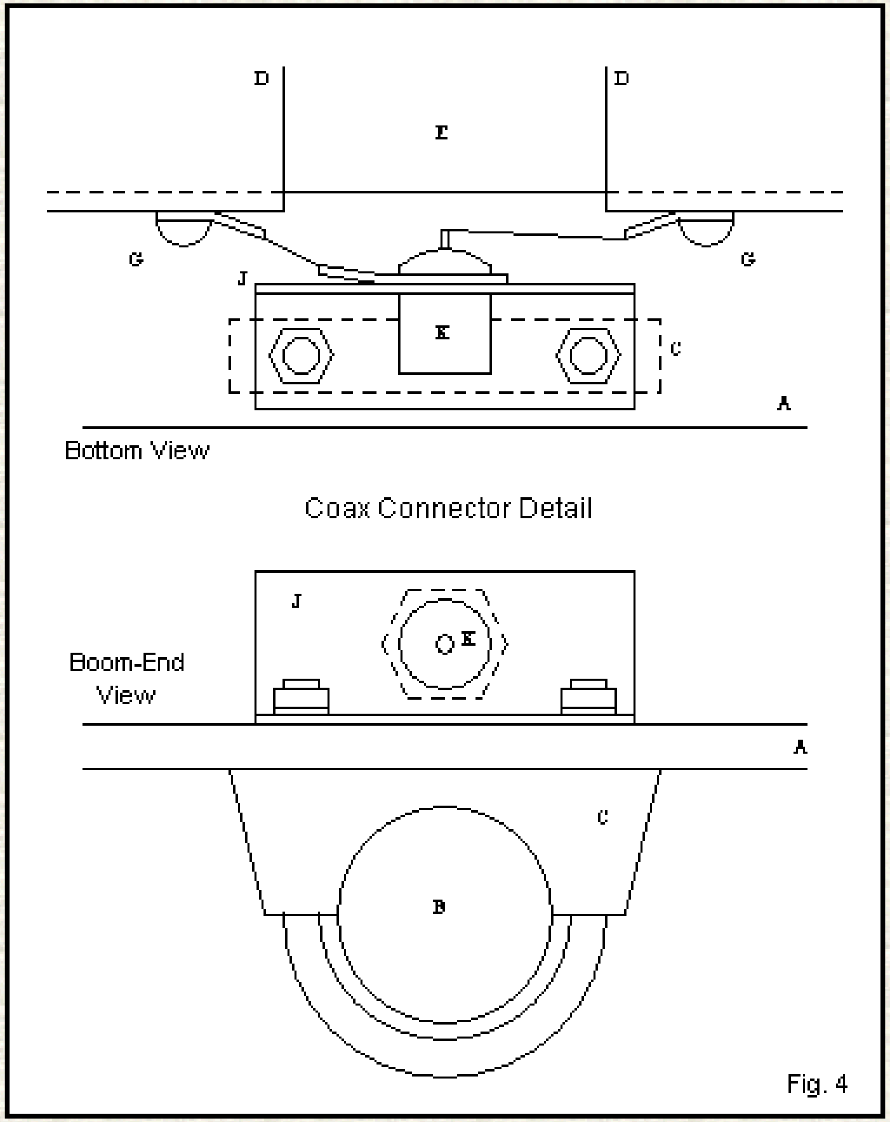


Fig. 4

The general ideas in these sketches permit any number of variations. Besides studying alternative techniques that appear in articles and handbooks, you may also examine various commercially made beams that you encounter. Very often, manufacturers place their assembly manuals on line for the benefit of prospective buyers and those who obtain beams second hand. These manuals are excellent sources of ideas ready for your local adaptation.

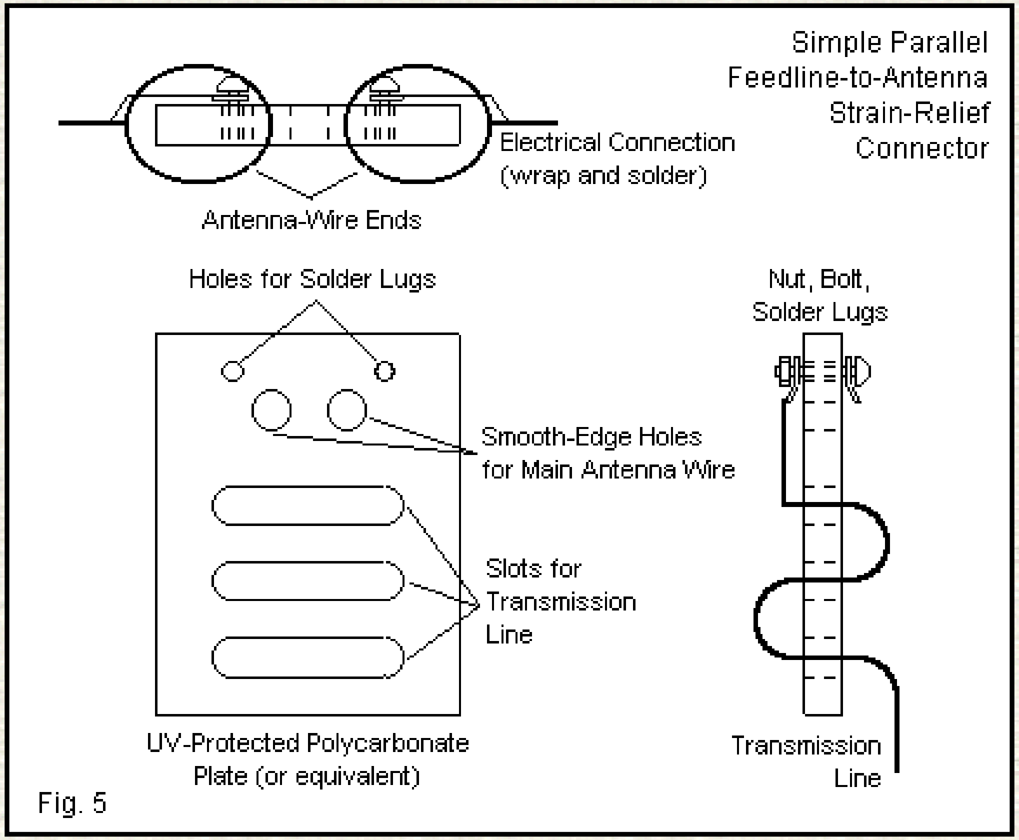
Whichever system of mounting that you use, be certain that the assembly has the quality necessary for durable service. Most beams operate at the tops of expensive towers with equally expensive rotators to direct them. The antenna itself should not be a weak link in this otherwise sturdy system.

Wire Antenna Hardware

Wire antennas deserve as much attention as beams, although the hardware may differ. Hard-drawn copper wire is generally satisfactory for most wire antennas, although copper-clad steel is perhaps the most durable material. However, it is harder to use, since it does not want to straighten out from its packaged coil shape. Beware of soft-drawn copper wire, since it will stretch and eventually break from its own weight. Although the merits of solid vs. stranded wire have sometimes led to abstract debates, I have never encountered any difference between the two for equivalent sizes. Most wire antennas may use insulated wire, although you will have to adjust the element length. Insulation adds an antenna (not a feedline) velocity factor that ranges from about 0.93 to about 0.98, depending on the insulation type and thickness. Hence, insulated elements will be physically shorter than equivalent bare wire elements. The concern for the length adjustment needed for wire insulation applies only to antennas that use precisely designed element lengths, such as wire Yagis. If you are setting up a multi-band center-fed doublet, the precise length is not critical, since you will be using parallel feedline and an antenna tuner.

Center or Feedpoint Connections

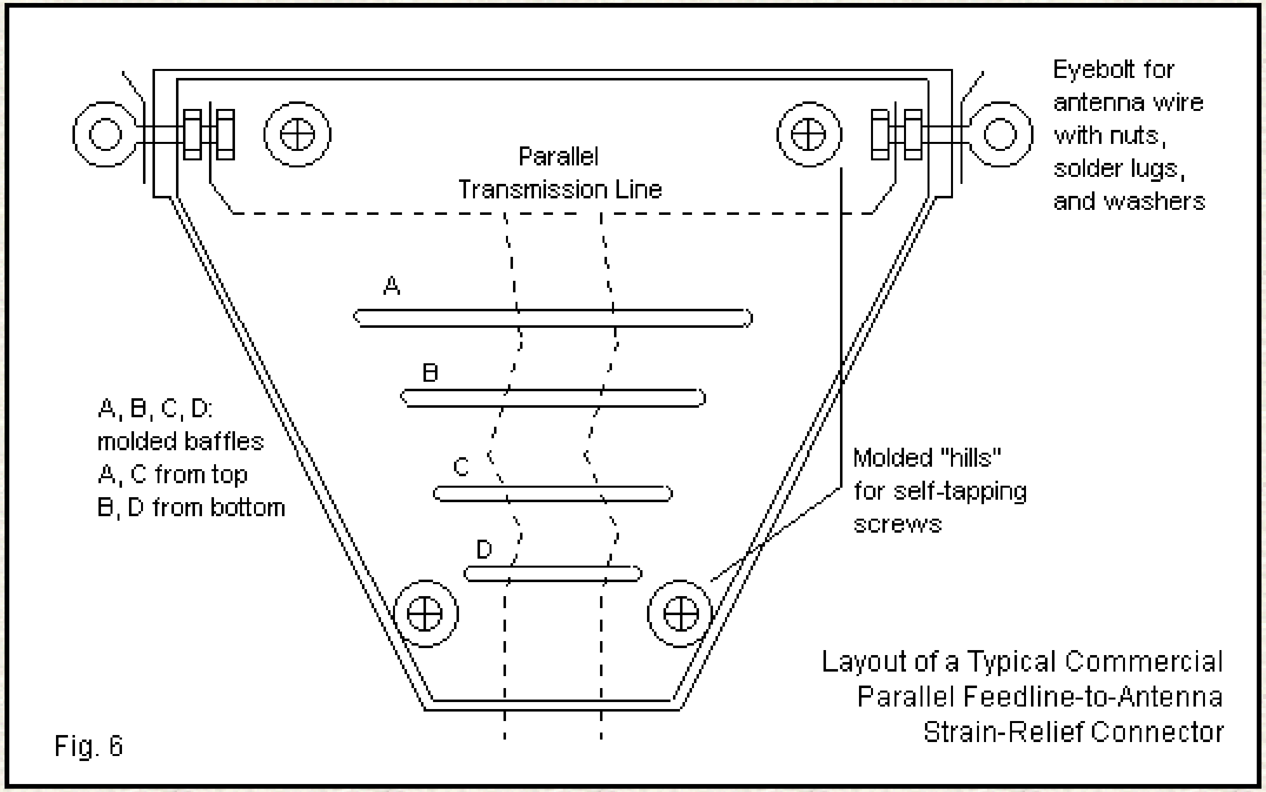
For simple dipoles or other antennas with low feedpoint impedances that require coax connectors. there are numerous inexpensive commercially made feedpoint connectors constructed from various plastic materials. Some units include a 1:1 balun to attenuate common-mode currents--a wise precaution for any antenna directly fed by coaxial cable. However, our selections are fewer when we use a parallel feedline. Very often, wire antenna builders use a simple insulator and just solder the feedline to the antenna wires. Unfortunately, this common practice results in feedline flexing at the junction, with a line break in almost no time. A better system is to devise a center insulator that also provides strain relief for the parallel feedline.



The polycarbonate UV-protected plate in **Fig. 5** has some critical holes that we can easily fashion at the workbench. All of the holes and slots through which we pass wires should be filed to produce smooth rounded edges. The antenna wire holes will benefit from short lengths of plastic tubing through which the antenna wire passes. The effect is similar to the use of a thimble used with rope and wire cable ends. The stress on the wire is distributed over a small length rather than being concentrated at a single point.

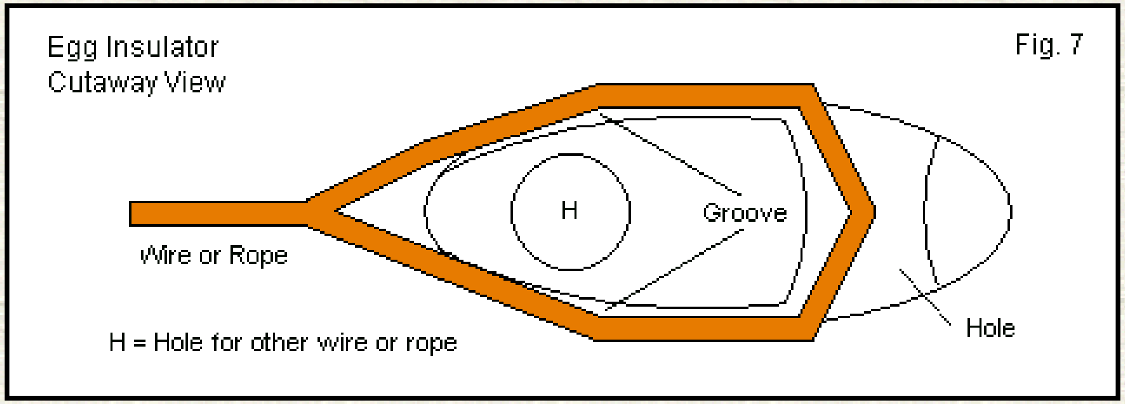
The slots allow you to weave the feedline and thereby virtually eliminate the stress at the line ends. Hence, we may use simple wraps or solder lugs to terminate the line and to provide a separate lead to solder to the antenna wire. Note that the feedline connection to the antenna wire occurs at the place where we normally wrap and solder the antenna wire. This system prevents antenna wire movement from stressing the feedline. Use stainless steel nuts and bolts, of course. You may cover the junctions with products designed as "liquid" electrical tape.

The simple plate achieves the same goal as the few commercially made assemblies for joining antenna wire to parallel transmission line. **Fig. 5** shows the general principles used by such devices. Because the units can consist of two molded pieces clamped together by assembly screws, they tend to replace the slots in the homemade version with alternating bars molded into the casing. Once we close the case, the parallel feedline cannot move. The other difference from the homemade assembly is the use of eye-bolts for the antenna wire.



The Other End(s) of the Wire

Whether home-made or commercially made, these connectors are applicable to any wire antenna feedpoint using parallel feedline, whether we locate the feedpoint at the center, off center, or at the end of the wire antenna. However, wire antennas have either 1 or 2 loose ends that we need to join to a support rope. **Fig. 7** shows one of my favorite types of insulators and strain-relief devices for wire antenna ends. The sketch portrays a cutaway view of an "egg" insulator. The antenna wire and the support rope at right angles to each other. Hence, by showing the wire, the rope disappears from view.



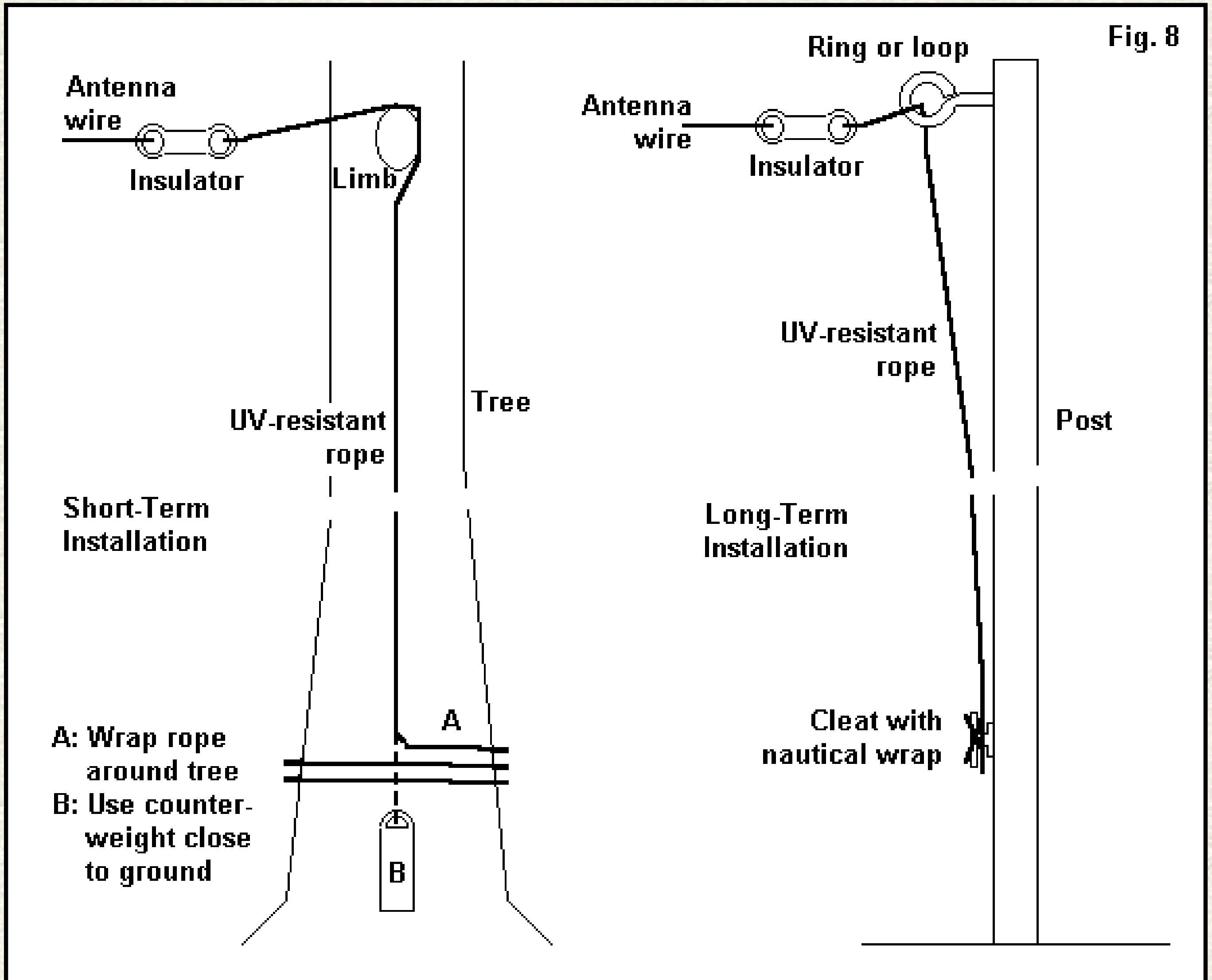
We might use a common bar insulator in this application. When we used guy wire as the chief antenna end support material, we often needed bar insulators to prevent the high voltage at the antenna ends from arcing to the guy wire as the assembly gathered grunge from the atmosphere. However, since rope supports are now nearly universal, the egg insulator is both usable and beneficial. The egg insulator creates its own thimble for stress relief by the molded slots in its ceramic structure. Additionally, if the egg should crumble, the wire and rope are linked until we can replace the insulator. (However, I have never broken an egg insulator, even by dropping one in the shop.)

I have noted the universal use of rope as a support material for wire antennas. Not all ropes are created equal. For antenna support, use one of the multi-layered UV-protected ropes designed expressly for this job. Almost anything else (except perhaps for Phillystran) will eventually break either from sun exposure or from the effects of precipitation.

Supporting the Wire

When we think of supporting the ends of a wire antenna, we often let haste make great waste. Never tie off the end of a wire antenna to a tree limb. The same applies to wire loop antenna for which we may use various trees and similar structures as intermediate supports. Under the continuous force of variable winds, the wire can act like a saw blade. Under certain conditions, high voltage can actually ignite wood. We think of wood as an insulator. Properly treated, it can be an effective insulator in the lower HF region. However, live trees and raw wood are more like a semiconductor, where the resistance varies with the wetness of the material, both inside and outside.

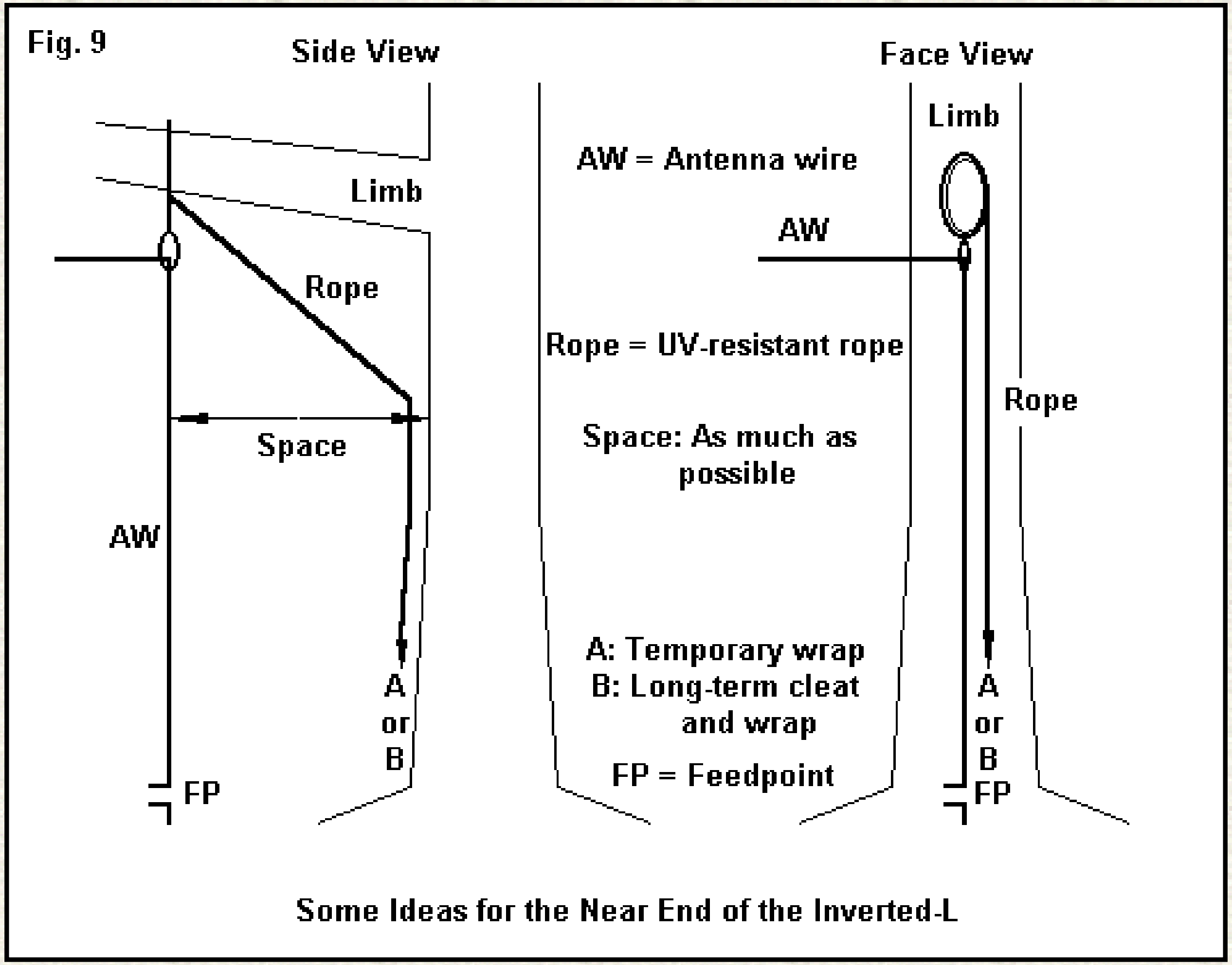
In addition to durability and safety, we should also think of convenience when we install a wire antenna. Every antenna deserves a close inspection every 6 months. If we can easily lower the antenna, we can reduce maintenance time to under an hour, including cleaning the insulators and wire and applying a thin coat of non-conductive liquid polish to the antenna wire. **Fig. 8** shows some (but not all) ways of adding convenience to our list of antenna assembly properties.



Some Ideas For Handling the Ends of Wire Antennas

At the upper end of the system, we have the wire termination (using a bar insulator in this case), with the support rope passing over a limb or through an eye-ring attached to a post or trunk. If you use a screw-type fixture with a tree, expect the tree to over-grow it within a few years. The rope then proceeds nearly to ground level. The sketch shows 3 different ways of handling the loose end. For short-term use, we can wrap the excess rope around the trunk or post. However, if the tree is living, then we must re-wrap the rope once a year to prevent girdling the tree. We can also install a weight that will let the rope slide as the tree sways. However, this technique requires us to create a safe system that will not let the weight harm people or pets. The third system uses a stainless steel cleat with the rope forming an effective nautical wrap. We do not have to keep all of the rope needed to lower the antenna at the termination point of the system. Rather, we keep only enough excess to create a good lock. When we need to lower the antenna for maintenance, we can add rope to the end before we lower the antenna.

A popular and effective wire antenna is the inverted-L. The antenna structure includes both a vertical and a horizontal portion. One mistake often made by first users is to run the vertical section next to a tree trunk. The result is usually very poor antenna performance and a tree that is overstuffed with RF.



As shown in **Fig. 9**, we need to devise an installation that places the vertical section of wire as far from the tree trunk as may be feasible. We can use the same general support system, but notice that the wire does not run over the tree limb. Rather, it runs through a ring supported by the rope that we attach to the tree and pass over a handy limb. If you have two trees, then suspending a rope between them and running the inverted-L wire up to a center point would further reduce losses from RF-eating trees. These same principles would apply to suspending a wire vertical monopole from a high point in the tree canopy.

Near-Ground Concerns

Vertical monopoles and inverted-Ls ordinarily place their feedpoints at near-ground level. Our thoughts at this junction should include mechanical and electrical soundness, as well as safety. The termination on the left in **Fig. 10** shows a good use for the modern generation of waterproof remote antenna tuners. Placing the tuner at the feedpoint of the multi-band antenna allows a buried coax run to the shack. However, I very often see antenna builders connect the antenna wire directly to the tuner terminal. If certain things go wrong, the tuner might be mechanically damaged from excess strain exerted by the antenna wire. Hence, the sketch also shows a rod and non-conductive plate that serves as an intermediary. A short line goes from the tuner to the plate, which bears the stress of the antenna wire.

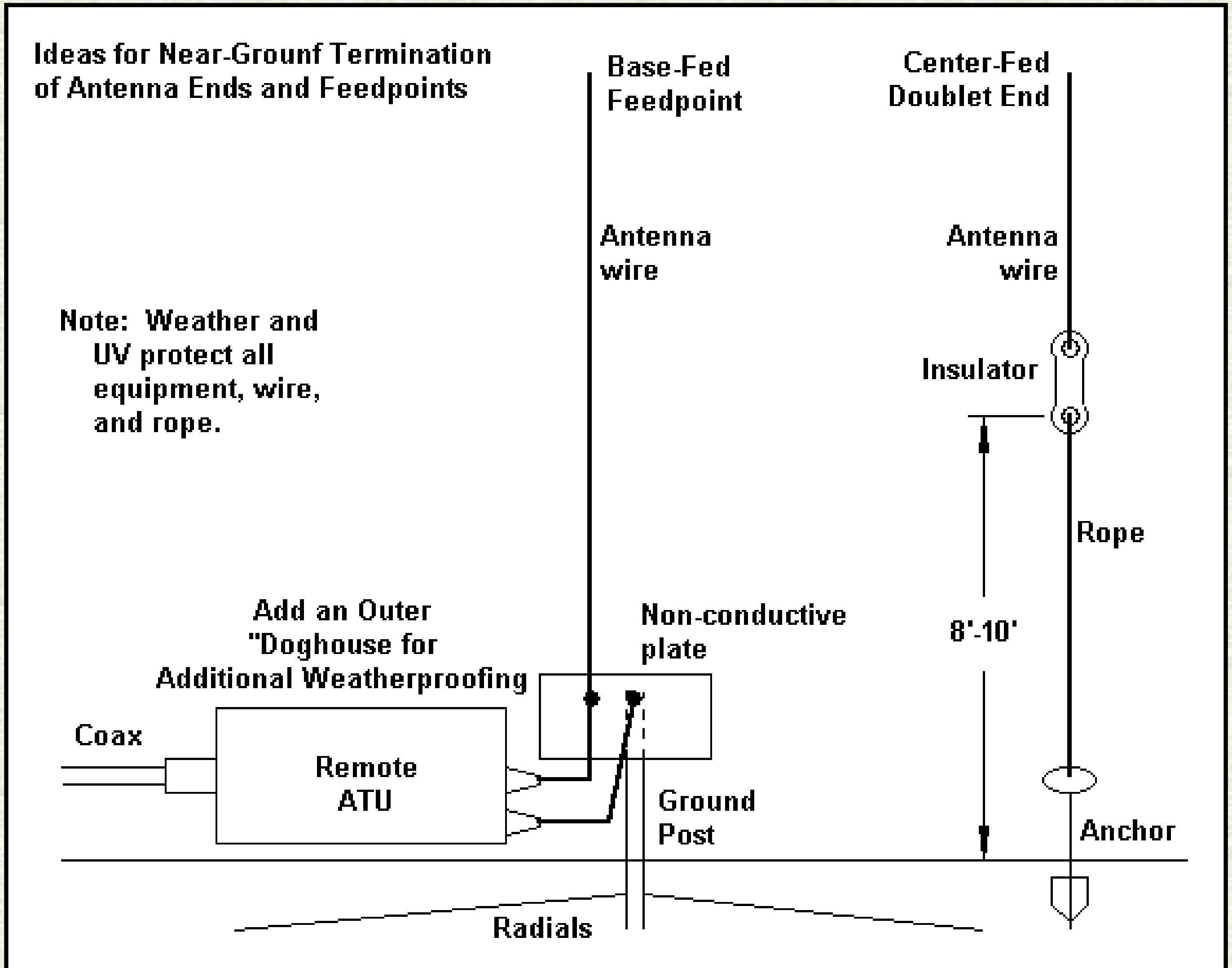


Fig. 10

In addition, the rod also serves as a focal point for grounding at the tuner-antenna junction. The tuner's ground terminal connects to the rod via the plate, while a set of radials extends from the rod outward. The radials may serve only the needs of the antenna. However, a smarter procedure would be to set up the radials in accord with standards for dissipating lightning energy as well. The terminals on the plate should have a means of shorting the antenna to ground and disconnecting the tuner when an electrical storm is in the area (or, better, whenever the antenna is not in use).

The right side of the sketch shows the far end of an wire antenna, which might be any wire antenna that needs to bring that end toward the ground. For safety, the end is at least 8' to 10' above ground, that is, above the highest point that a person or pet might jump. A rope keeps the wire end taut by virtue of being anchored to the ground.

The picture is not yet complete. The anchor has a portion above ground that might prove physically hazardous. The antenna tuner terminals and the plate terminals are both exposed to touching, either intentionally or accidentally. **Fig. 11** shows one type of remedy for these conditions. The tall non-conductive conduit protects an individual from making physical contact with the antenna. At the other end of the wire, it would prevent an individual from tripping over the anchor. As a second line of defense, one might also plant a small circular flowerbed around the conduit, complete with a small (6"-8") picket fence or other border.

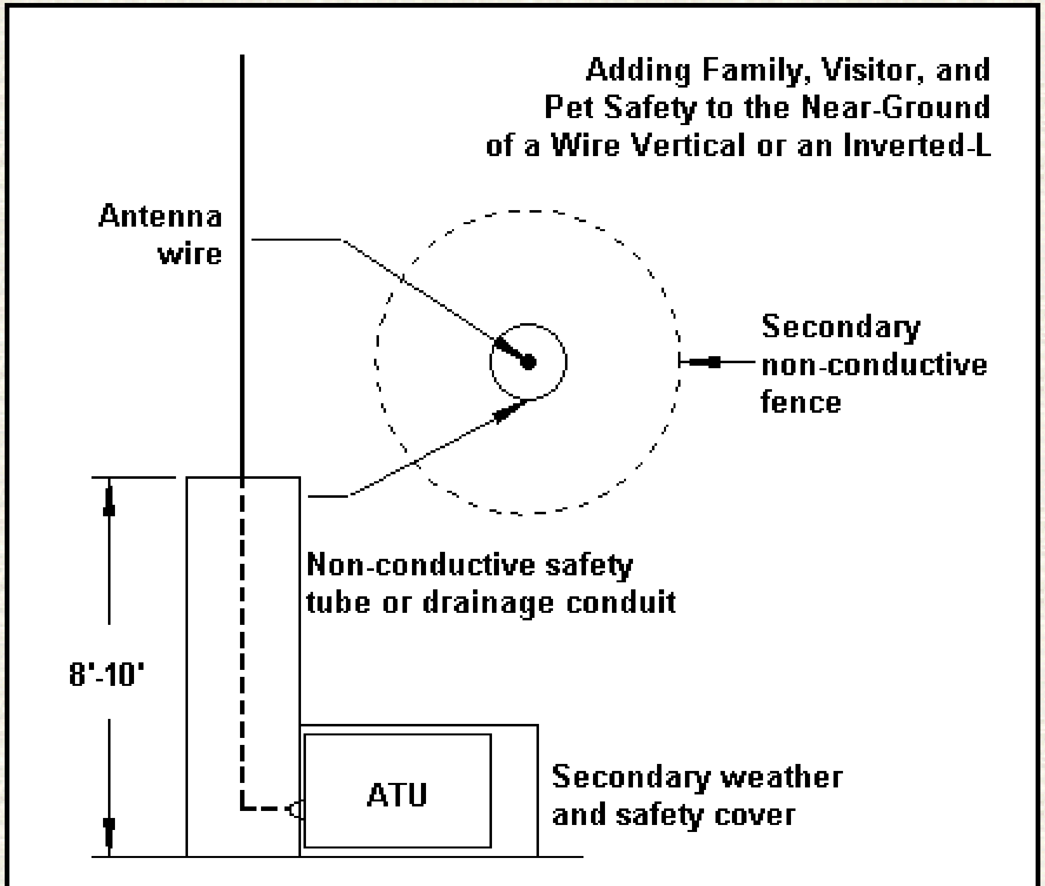


Fig. 11

At the feedpoint end of the system, the tuner has an additional protective housing connected to the conduit. The housing serves several purposes. First, it prevents contact with the antenna terminals. Second, it allows us to elevate the tuner above ground to prevent the unit from lying in water. Third, it keeps rain and snow from falling directly on the unit, reducing the test load that we place on its waterproof claims.

Implementing all of these wire-antenna techniques--or any reasonable variations upon them--is not very expensive. However, they can together keep our antennas working longer with less potential for harm to people, pets, or property.

Conclusion

This collection of notes represents some of the HF practices that seem to have serve me well over a large number of years. They do not show the only way to achieve our goals when building beams and wire antennas. Instead, they show only one set of ways. However, with the explanations of why I do what I do in the way that I do it, you should be able to develop methods for arriving at the same goals with different and even better methods.

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