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In practice

DRILLING THROUGH ROUND TUBING

Q: ***I would like to try building some long Yagi antennas. How can I drill accurately through a round boom? Also, how can I keep all the elements in line, and not end up with something that looks like a corkscrew?***

A: The best advice I can offer is: don't use round tubing for the boom – use square tubing instead. The only real advantages of round booms are a slightly lower wind resistance per unit weight, and a significantly lower cost for commercial manufacturers. Set against this, square booms are much easier for home constructors. They are easier to drill, with automatic alignment of elements and better support against the elements rocking in the wind. Square tubing is also self-aligning in mast clamps and U-bolts. And although square tubing is available in fewer sizes than round, in practice it is very easy to splice and telescope sections together using simple flat shims.

An element mounting almost always involves two holes drilled exactly through the centre-line of the boom. The holes for all elements must also be exactly in line, so that the elements will all lie in the same horizontal plane. This creates a number of problems, all of which are much worse for round tubing. It is difficult to find and mark the centre-line accurately, and also the top of the tube is convex, so ordinary twist drills have a strong tendency to skid off and break. So what you need is some way to support the drill bit, and guide it exactly through the centre-line of the tube.

If I haven't convinced you to use square tubing instead, here are some answers for cross-drilling through round tubing. These are about the simplest solutions that will actually *work*, without breaking large numbers of drill bits. I've also tried to think of the simplest method that can be used with an ordinary hand-held electric drill, or at most a basic pillar drill. (A small pillar drill can be very cheap, these days. If you don't already have one, it's worth considering in your letter to Santa.) If you have access to more advanced machine tools, then of course there are lots of better ways... and you won't be needing this advice.

About the simplest kind of drilling jig is a channel to locate the tubing, with a guide block on top which locates and supports the drill bit (**Fig 1**). The whole thing can be made from wood, and with a little thought and planning you can reduce the number of precision operations required to just one. You will need the following materials:

- A strong, flat piece of wood for a base plate.
- A strip of planed softwood or hardwood for the two sides. The thickness should be the same as the diameter of the tubing, or just a little larger.
- A substantial chunk of *hardwood* or similar for the guide block.
- Some wood-screws and PVA wood glue.

The sequence of construction is as shown in Fig 1:

1. Glue one side strip to the base plate. (Clamp the pieces firmly while the glue sets.) We'll call this the 'fixed' side strip.
2. Drill a hole through the guide block, of the correct diameter for your element mounting, and accurately at right-angles to the bottom face. This is the only precision operation involved, and it really requires a well adjusted drill press (or if drilling by hand, be prepared to throw away a lot of scrap pieces before one comes out right).
3. Drill a pair of holes in the guide block for wood-screws to attach the block to the fixed side strip, so that the hole drilled in step 2 will pass exactly through the centre-line of the tube as shown in Fig 1. Make these screw holes slightly over-size, so that you'll be able to position the guide block precisely in steps 4-6.
4. This is the trial-and-error part. Loosely assemble the whole jig with a scrap piece of tubing, and adjust the positioning of the guide block until you can drill exactly through the centre of the tube. How can you tell? Remove the tube, turn it end-for-end and slide it back into the jig; if the jig is accurately aligned, the drill bit will slip easily through all the existing holes.
5. Slip the drill bit through the guide block, through your 'good' pair of holes in the tube, and into the hole in the base plate. The drill bit will pin the tube in place against the base plate and the fixed side strip, so you can easily remove the guide block and replace it accurately. Now that you know where the guide block needs to be, drill through into the fixed side strip for the wood-screws that will hold the block down.
6. Smear the remaining joint areas with glue, and carefully reassemble the whole jig using the drill bit and the tube to align all the parts. Use washers under the wood-screws to allow some movement of the guide block before tightening the screws down.

The second side strip needs nothing but the glue to hold it in place – simply push it in to fit snugly against the tube. You'll have plenty of time to make adjustments before leaving the whole thing to set overnight.

Congratulations! You now have a 'good-enough' drilling jig for round tubing. It won't be a precision job, but it's certainly good enough for Yagi construction.

If you already have a pillar drill, another option is the drill guide available from Axminster Tools (see photo). It has a flat base with a 90° V-groove, so you can use it either to drill holes at right-angles into a flat surface, or to cross-drill accurately through the centre of a round tube or rod. The drill is guided by a steel bush; the kit

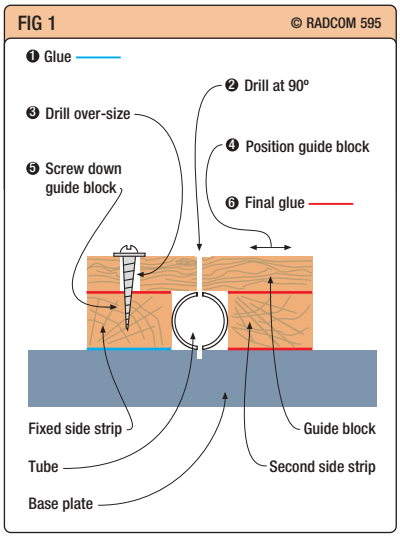
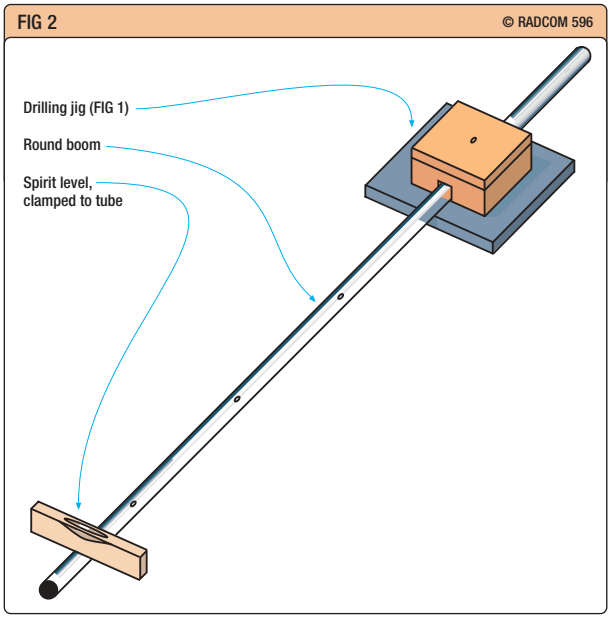


Fig 1
A home-made drilling jig for round tubing. Circled numbers refer to assembly instructions.

Fig 2
Use a spirit-level to help drill all the holes in line.

Fig 3
Distributed self-capacitance increases the apparent inductance. It can be approximated as a single shunt capacitor.



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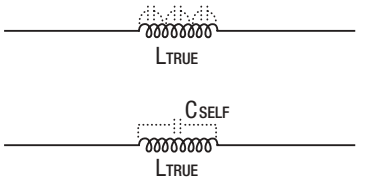
includes six bushes with a range of internal diameters, and also a scriber or centre-punch that fits accurately into one of the bushes. To use this guide, you would need to slip it onto the drill bit, shuffle the tube on the drill table until the bit runs freely, and then switch on and run the drill through... but you've probably noticed the drawback, which is that you don't have enough hands to hold everything safely. A jig like Fig 1 gives much better support for both the tubing and the drill point, and if you're using a pillar drill the jig can be clamped safely to the drill table. However, the Axminster drill guide can be used to drill an accurate hole through the guide block in step 2 above, and it will also make later parts of this job much easier (see below). At £6.94, it might well be worth a try [1].

Let's turn now to the second question: how to make sure that all your pairs of element mounting holes are accurately in line. One way is to slip a second drill bit through an existing hole, and rotate the boom until it lines up exactly with the drill bit in the jig. But unless you're careful it is easy to make errors of a degree or two, which will be very noticeable when the Yagi is in the air. A more accurate method is to clamp a spirit-level across the tube (Fig 2) and make sure the bubble is centred, every time before you drill. If you're using a drilling jig like Fig 1, that will accurately line up all the holes.

Most Yagis use more than one section of boom, so begin by drilling all the element holes in each section separately. At the joints where two boom sections telescope together, only drill through the *outside* section with a pair of small pilot holes. When you come to assemble the whole Yagi, rotate the joints to line up all of the elements by eye, and then run the pilot drill right through each joint. Finally, drill out the pilot holes to full size and connect the boom sections together. This part of the job will probably have to be done outside, with a hand-held electric drill, so here's the second place where the Axminster drill guide could be very useful.

Well, now you know how it *can* be done... but hasn't this persuaded you to use square tubing instead?

FIG 3 © RADCOM 597



Drill guide from Axminster Tools.

CAN INDUCTANCE VARY WITH FREQUENCY?

Q: ***My R – X impedance analyser shows that the inductance of a coil seems to increase with frequency. Is this a fault?***

A: Probably not. This question is almost as old as radio itself, but is only now coming to the attention of most amateurs. What's new is that many more of us now have test instruments that can make quick and simple measurements of inductance and capacitance at the actual RF operating frequency. But maybe it's not so simple after all...

The inductance of a coil is created by magnetic coupling between each turn and all the other turns. However, in any practical inductor there is also coupling between the electric fields of different parts of the coil, which results in 'self-capacitance'. Inductance is independent of frequency, but at higher frequencies the self-capacitance will begin to affect the *apparent* inductance – which is all that a test instrument can actually measure.

To see what's happening, we can approximate the self-capacitance as a single capacitor in parallel with the inductance (**Fig 3**). Then the apparent inductance is given by:

$$1/X_{L,\,APP} = 1/X_{L,\,TRUE} + 1/X_{C,\,SELF}$$

$$1/(2\pi fL_{APP}) = 1/(2\pi fL_{TRUE}) - 2\pi fC_{SELF}$$

At low frequencies, the reactance of the self-capacitance ($X_{C,\,SELF}$) is very large, so the measured value, L_{APP}, is very close to the actual inductance, L_{TRUE}. But as the frequency increases, $X_{C,\,SELF}$ becomes smaller and has a noticeable shunting effect. This makes the *apparent* inductance increase with frequency, up to the point where L_{TRUE} and C_{SELF} become parallel resonant and the apparent inductance shoots up to infinity.

Above that self-resonant frequency, f_R, self-capacitance dominates and the 'inductor' will appear to be capacitive. A properly functioning R-X impedance analyser will faithfully report all of this, along with generally smaller effects caused by resistive losses.

For frequencies up to about 80% of the self-resonant frequency, f_R, and for inductors with low resistive losses, a useful approximation to extract the value of L_{TRUE} from the measured value L_{APP} is:

$$L_{TRUE} = [1 - (f/f_R)^2]L_{APP}$$

SUPERGLUE TIPS

These are follow-ups from the December 2004 column on adhesives, and are specifically about cyanoacrylates or 'superglue'.

From Richard, G3RWL: "When you buy superglue there is always more than you need, and it tends to go off before you can use it all (typically six months to a year). The solution is to stopper the bottle tightly and keep it in the fridge; it'll remain usable for several years.

"When superglue is getting somewhat old, the setting time is longer, sometimes minutes. To speed it up, put it under water (remember that it works on the exclusion of air). This isn't always convenient, but if you can hold the joined pieces together, a dip into a washing-up bowl full of water for half a minute usually does the trick."

From Peter, GM8GAX: "If you make a mistake when using superglue, the bond can easily be released by applying a little heat. Heat to approximately 150 – 180°C and you will be able to separate the joint quite easily. Clean off the surfaces and start again. Obviously this tip applies mostly to glued joints between metal components, as many thermoplastic components can't withstand the temperatures involved."

GARDENING TIP

In the tradition of 'Gardeners' Question Time', here's a seasonal tip for all you antenna growers.

Late October or early November is a good time to give your lawn a last cut, and to plant some radials for your new low-band vertical. If you cut the grass really short, and peg the radials down onto the surface, then by springtime they'll already be disappearing under the new season's growth. ♦

REFERENCE

[1] Axminster Tools (0800 371822) order code APTCUDG. Follow the links from the 'In Practice' website.