If the impedances of your antenna and feedline are as far apart as your and the tax inspector's estimates of your income, then you may need a quarter-wave transformer for your antenna system.

The Quarter-Wave Transformer

BY GEORGE MURPHY*, VE3ERP

For years the handbooks have been telling us a quarter-wave transformer matching section will match almost any antenna to almost any feedline. This statement is usually accompanied by a diagram similar to fig.1 and a variation of the quarter-wave transformer equation shown in the sidebar.[1] Like many other non-technical amateurs, I generally have avoided the quarter-wave transformer because I could only guess at the actual operating load impedance of my antenna. And even when I used what I thought might be a reasonable guess in the equation, it always seemed to come up with some weird impedance for the matching section. This led me to believe I had guessed wrong. Obviously, the first step in designing one of these devices is to eliminate the guesswork. You have to measure the impedances of both the antenna and feedline.

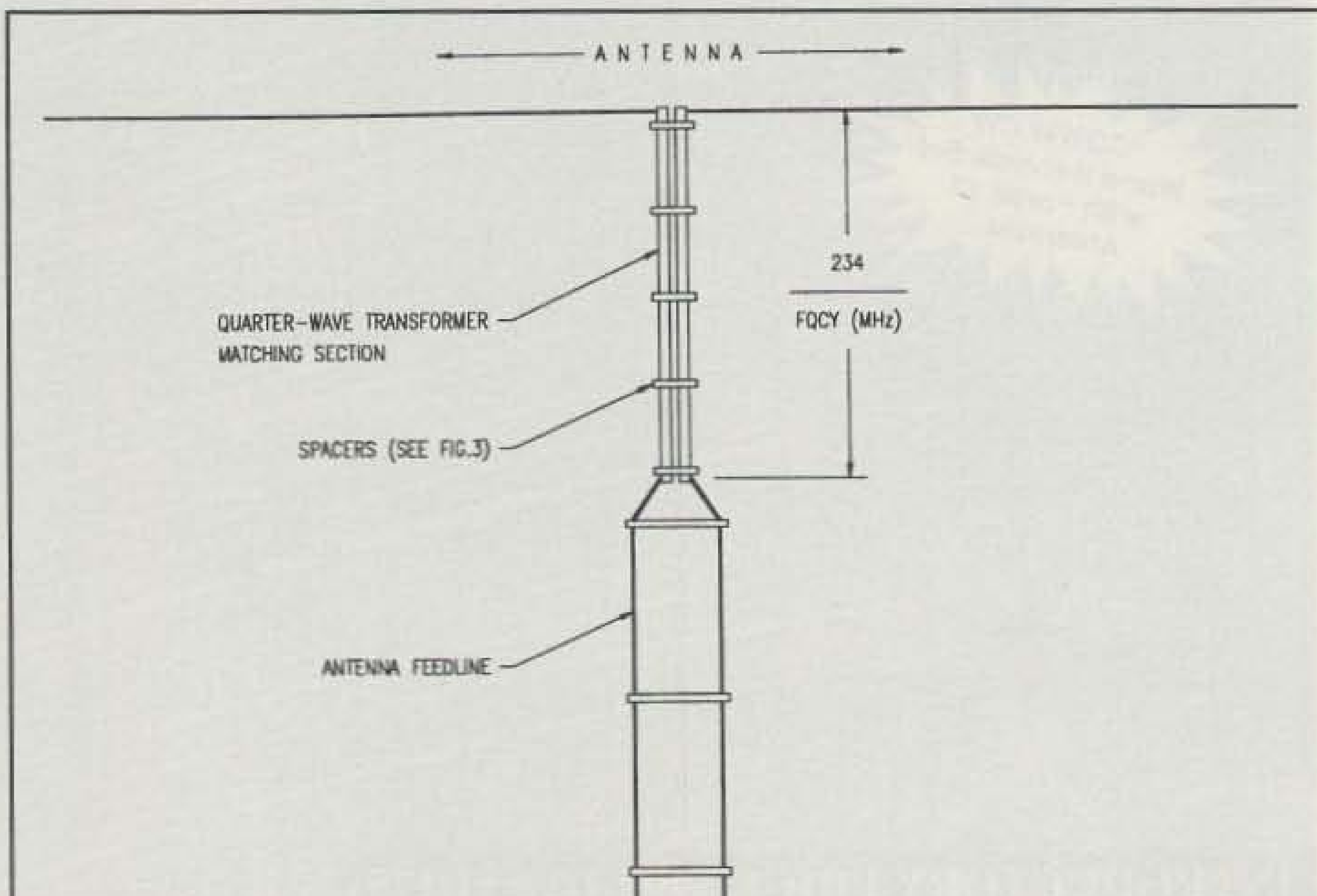

Fig. 1– Typical quarter-wave matching section as described in many handbooks.

Determining Impedances

Antenna impedance can be found in the comfort of your shack[2] by measuring the impedance at the input end of the transmission line with one of the current crop of small, affordable antenna analyzers. If you don't have one, you can homebrew one.[3]

If you are not sure what the impedance of your feedline is, it can be calculated with the open-wire equations presented in the sidebar or it can be read directly on the graph in fig. 2.

Once the impedances of both antenna and feedline are determined the required impedance of the quarter-wave matching section can be calculated with the transformer equation shown in the sidebar.[4] This is where the fun starts.

Your application may call for a matching section impedance far removed from any available standard store-bought open-wire line, so you may decide to make your own. Start by consulting fig. 2 again or by going back to the open-wire

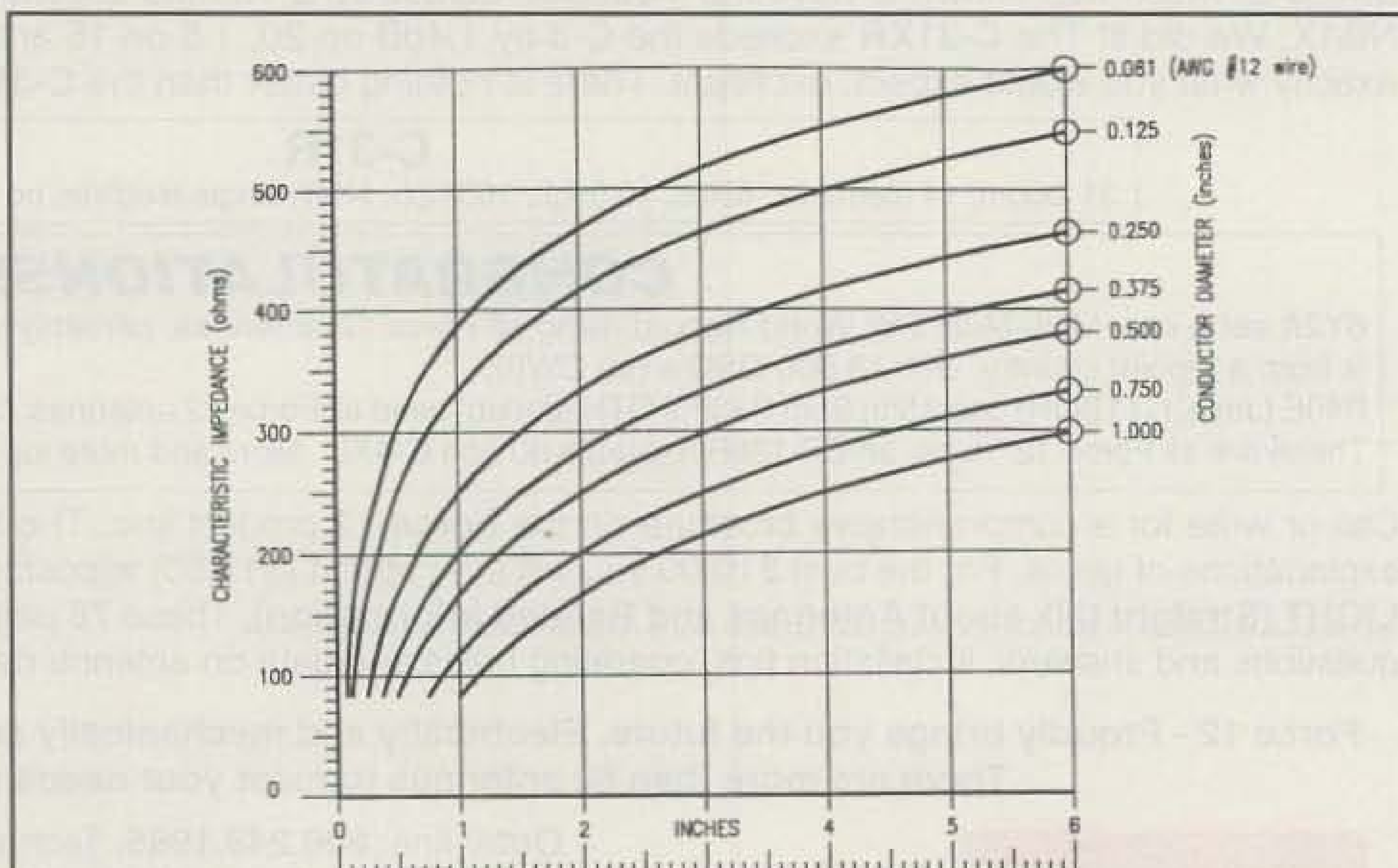

Fig. 2– Open-wire transmission line conductor spacing.

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QUARTER-WAVE TRANSFORMER EQUATION

$$Z_0 = \sqrt{Z_i Z_L}$$

where:
Z_0 = characteristic impedance of matching section
Z_i = impedance at input end of matching section
Z_L = impedance at load end of matching section

2-WIRE OPEN-WIRE LINE EQUATIONS

$$Z_0 = 276 \log_{10} \frac{2S}{d} \qquad n = \frac{Z_0}{276} \qquad S = 10^n \frac{d}{2}$$

where:
Z_0 = characteristic impedance of line
S = center-to-center spacing of conductors
d = diameter of conductors
S and d are in same unit of measure

AWG (American Wire Gauge) EQUATIONS

$$D_M = \frac{11.68}{1.123^{(n+3)}} \qquad D_I = \frac{.46}{1.123^{(n+3)}}$$

$$n = \frac{\log \frac{11.68}{D_M}}{\log 1.123} - 3 \qquad n = \frac{\log \frac{.46}{D_I}}{\log 1.123} - 3$$

where:
D_M = wire diameter in millimeters
D_I = wire diameter in inches
n = AWG number

equations to determine the size and the spacing of the conductors required for the transformer.

The Matching Section

At this point you may encounter an inherent bothersome fact about open-wire lines, which I call TFTFT (pronounced "tftft!")—the Too Fat To Fit Together syndrome. At impedances below 84 ohms the spacing between conductor centers becomes greater than the conductor diameter, as shown graphically in fig. 2. This is not a real problem, because in this range of impedances coaxial cable or commercial 75 ohm twinlead can be used for the matching section. However, the distance between conductors probably will be very close, in which case it is advisable to use tubing because of the difficulty of maintaining accurate spacing and parallelism if you try using wire.

Construction Notes

Fig. 3 shows the major construction details. Aluminum is an excellent choice for the tubing because it is lightweight and easy to cut and drill. If there is a physical support where the transformer is attached to the antenna, then copper pipe or tubing, although relatively heavy, is recommended. This is because the antenna elements and feedline can be soldered directly to the tubing, thereby eliminating the inevitable corrosion caused by electrolytic action between dissimilar metals (e.g., copper and aluminum) in contact, whether clamped, soldered, or welded.

You will need some small wood blocks about 12 mm (1/2 inch) thick, of a size to suit the "d" (diameter) and "S" (spacing) dimensions of the transformer, as shown in fig. 3(A). Clamp them together one pair at a time and drill two holes the same diameter as the conductors. It is a good idea to mark identification numbers on each pair of blocks, because if you are as unhandy a handyman as I am, the spacing will be slightly different (depending on the accuracy of your aim with a drill) on each pair. If the blocks get mixed up, you will have a tough time trying to fit them around the pair of tubes. Coat all the blocks liberally with a wood preservative and let dry. Finally, epoxy glue the block halves to each other and to the tubes, and then clamp them together until the adhesive sets.

As a rough guide, spacing between each pair of blocks along the transformer should be about 16 times the diameter of the tubing. Seal all the joints with silicone sealant, connect the antenna elements and the feedline, and haul the lot back up in the air before your XYL/OM discovers what you have been up to.

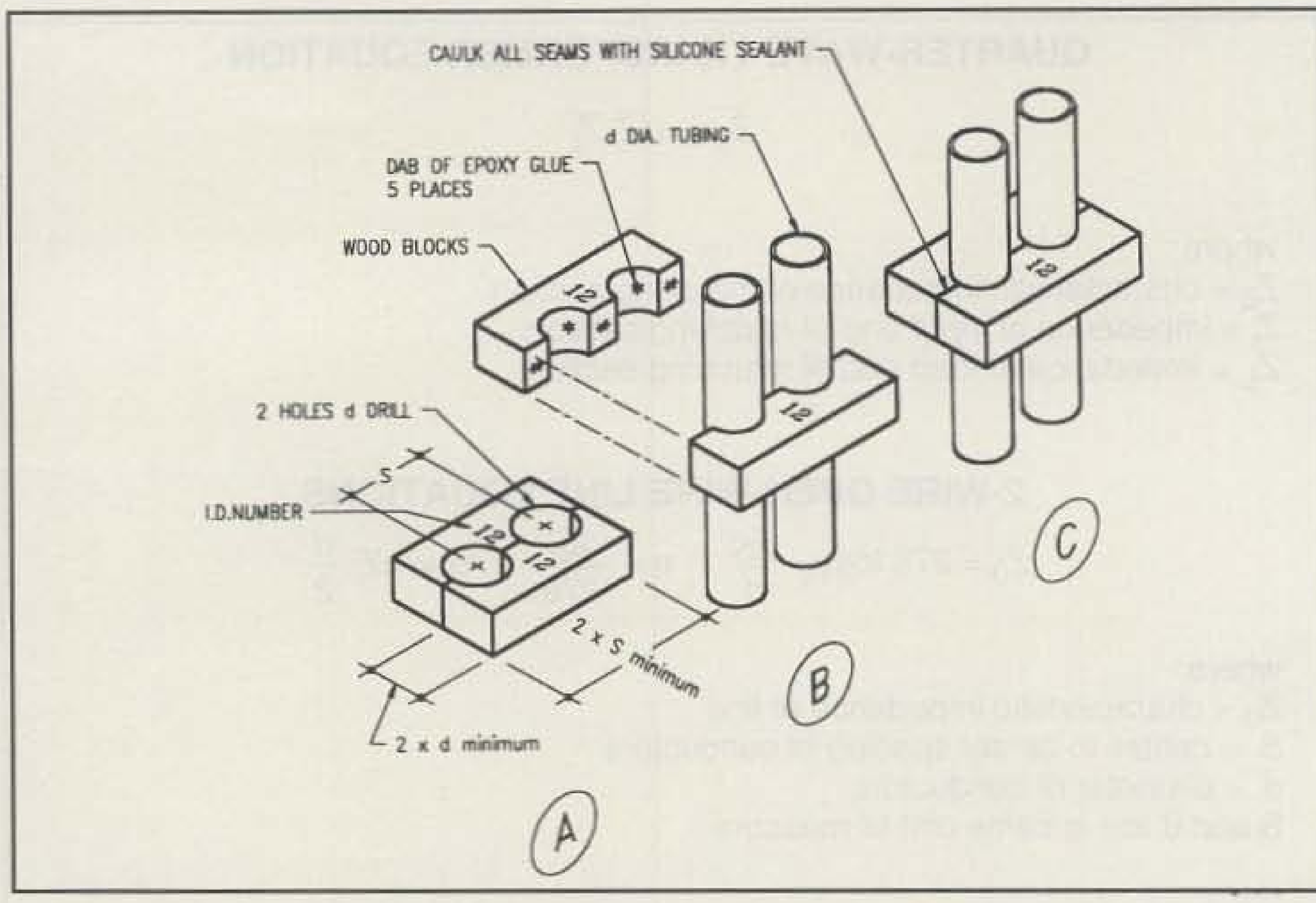

Fig. 3– Mechanical details for tubing supports when using tubing for matching line sections.

Footnotes

1. Don't let the equations intimidate you. You don't have to do any math at all if you have a computer and HAMCALC (Version 38 or later) software, which contains over 200 programs to do it for you. HAMCALC runs in MS-DOS or WINDOWS and requires a GWBASIC.EXE file in your root directory. To have HAMCALC on a 3 1/2 floppy disk airmailed anywhere in the world send US$5.00 (US$6.00 if you want a GWBASIC.EXE disk included) to the author of this article, at the address shown on the first page.

2. HAMCALC's "Impedance – Antenna" program does just that, if you feed it the results of a couple of simple measurements.

3. See HAMCALC "Impedance Bridge (3 meter)" program. It describes G3LDO's simple device consisting primarily of a single meter, a three-position switch, and a few junk-box components. When connected to the input end of an antenna feedline, readings at each of the three switch positions are entered into the program, which calculates the antenna impedance.

4. From this point on, the HAMCALC "Quarter Wave Transformer" program will do all the math required to complete the design of your matching section. ■