Paul Pauliukonis WD9AHH
741 Sixty-First St.
Downers Grove IL 60516

The Better Vertical

—elevated feed means low angle of radiation

How would you like to be a proud owner and user of an inexpensive (around \$60-\$70) vertical DX antenna which—

- Is self-supporting.
- Is attractive in appearance.
- Can be installed in a limited space.
- Gives a low vertical radiation angle even when it is one wavelength long.
- Can be used on all present and future amateur bands.
- Minimizes TVI because its radiation is vertically polarized and because harmonics are radiated at high vertical angles.
- Is safe from shock hazards because its base is grounded.
- Has a built-in lightning protection system.

If you answered in the affirmative, then this antenna is for you. This article describes how to build, install, and tune a 33-foot, elevated-feed vertical antenna.

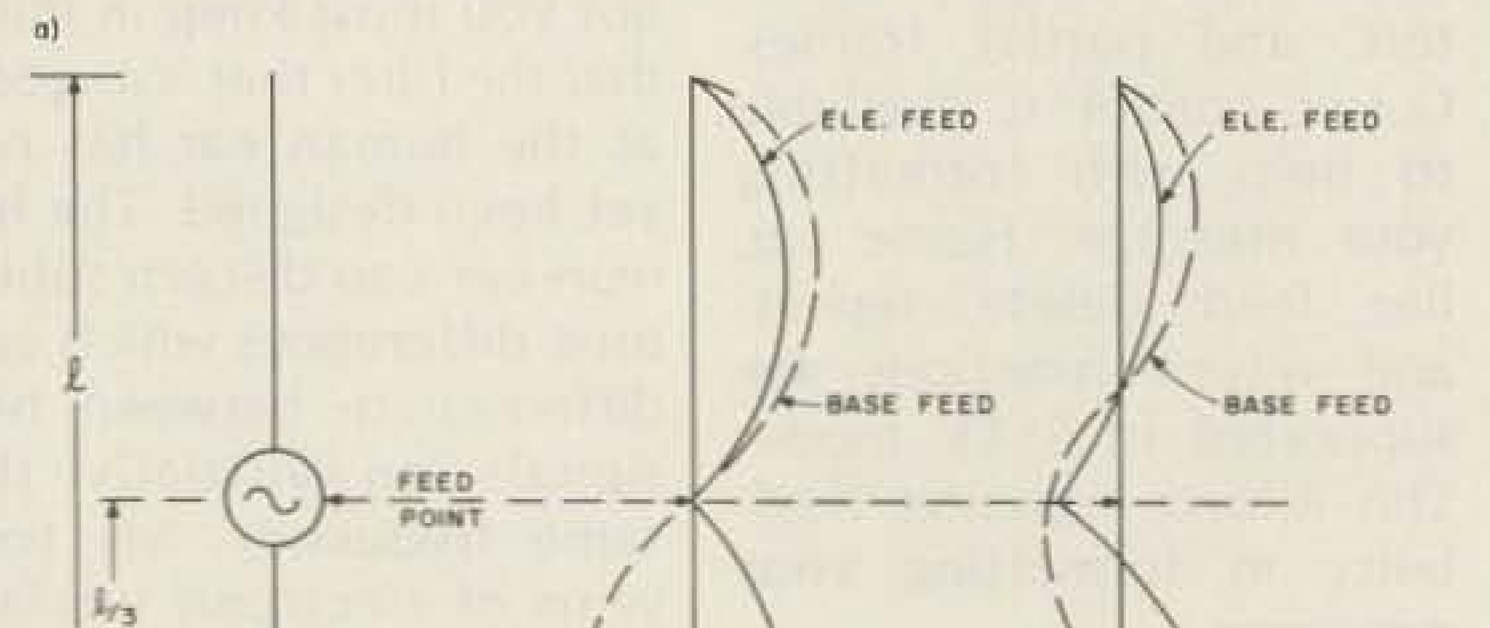

Fig. 1. (a) Current distribution and (b) vertical radiation patterns for 3/4λ and 1λ elevated-feed vertical antennas.

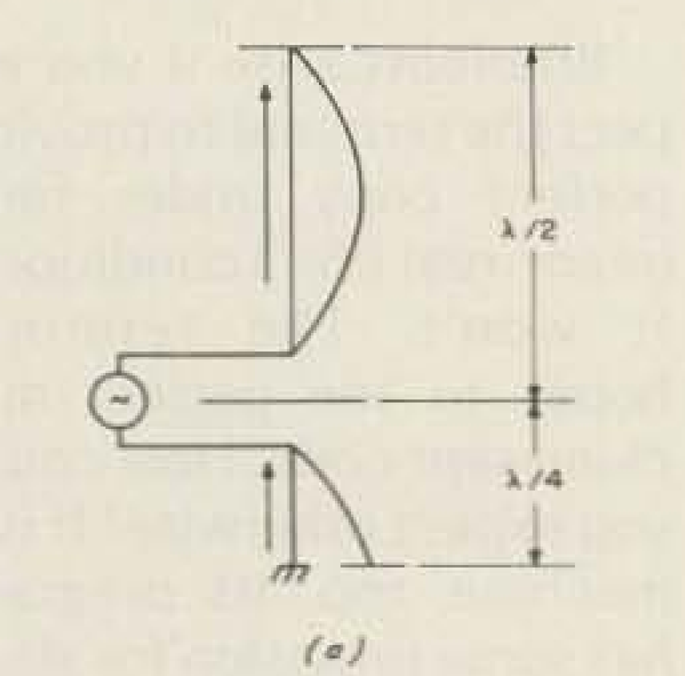

Fig. 2. Currents along antenna element for 3/4λ, elevated feed (a) and base feed (b).

Theory

An elevated-feed vertical antenna is not a vertical antenna which is elevated. It is a vertical antenna which is fed at a point which is 1/3 of its height from the ground—see Fig. 1(a).

I first came across the discussion of this antenna in *Amateur Radio Techniques*.[1] It contains a discussion of how an elevated-feed vertical antenna can be applied to amateur work to obtain "... low-angle radiation, without unwanted high-angle lobes, from vertical aerials of appreciable electrical length."[2] It explains how feeding a vertical antenna at the 1/3 point produces a current distribution different from that of a base-fed antenna. This is true only in cases where the antenna element is 3/4λ or 1λ long. If element length is 1/2λ or less, the elevated feed will perform approximately the same as a base-fed vertical antenna of the same height.

The comparisons of the current distributions and approximate vertical-radiation patterns for the base-fed and elevated-feed antennas are shown in Fig. 1. To understand how a low vertical radiation angle is achieved in the elevated-feed antenna, one should study the current distribution along an antenna element. *The ARRL Antenna Book* states that current is reversed every 1/2λ along the element.[3] Fig. 2(a) shows how this results in an inphase collinear array in the elevated-feed antenna which is 3/4λ long. This inphase current distribution along the antenna element is the reason for its low vertical angle of radiation. If the same antenna were fed at the base, the current distribution would not be in phase —see Fig. 2(b)— and an unwanted high-angle lobe would appear in the vertical plane as shown in Fig. 1(b).

Design Considerations

In the design, I gave priority to the following considerations:

(1) Limiting the design to a reasonable height.

(2) Incorporating a top hat to dissipate static charge.

(3) Positioning the tuning unit near the ground.

(4) Designing and building a strong yet inexpensive center insulator from readily available materials.

(5) Designing the antenna strong enough to be self-supporting.

I chose an overall antenna length of 33 feet as this would give me a full wavelength—the longest practical length for DX operation—on 10 meters. The 33-foot length meant that the upper section must be 22 feet because the antenna is fed 1/3 of the length from the ground. This would make it 1/2λ from the feedpoint on 15 meters, so I detuned it slightly to lower the impedance at that point. The optimum length of the upper section, as determined by 15-meter and 20-meter band impedance curves, was found to be 24.5 feet.

Because aluminum tubing comes in 8-foot sections, and because I would lose 2-feet in the bushings and overlap, the available length from three sections was reduced to 22 feet. To get around this limitation, I decided to enlarge the considered top-hat section to achieve the desired effective length. Four top-hat radials, each 1.3 feet long, were experimentally found to provide the missing link.

The prospect of climbing a stepladder to adjust the tuning unit did not appeal to me. To avoid this, I chose to place the tuning unit near the ground and to use a 12.5-foot section of RG-8 foam coaxial cable to carry the power from the tuning unit to the feedpoint. Theoretical approximation showed that, at the worst, an swr of 7:1 would be present. The additional power loss for a 12.5-foot section of RG-8 foam cable with an swr of 7:1 was found to be 0.25 dB. I preferred this to climbing the ladder.

Power limit at an swr of 7:1 is found by dividing the power rating of the cable at an swr of 1:1 by the swr under operating conditions.[4] For this application, this is 2200/7 = 314.3 Watts. The output from a kW linear should be approximately 500-600 Watts. For intermittent duty, the average power would be half of this figure, or some 300 Watts. This does not give much of a safety factor, but I decided to go ahead and worry about it when and if I acquired a linear.

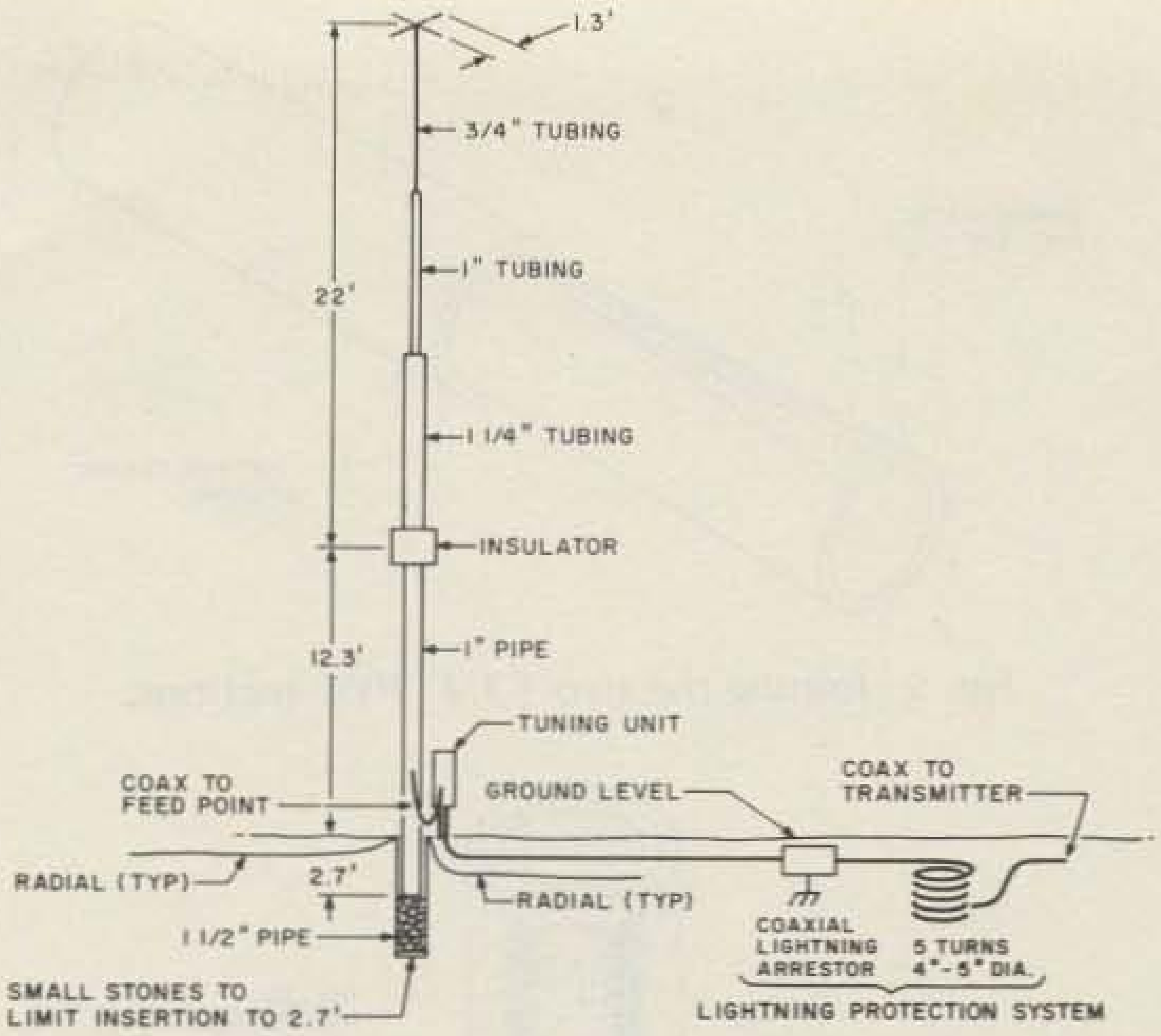

Fig. 3. Final design of the elevated-feed vertical antenna.

To make the antenna as attractive as possible, I designed it strong enough to be self-supporting. This presented no great problem except for the center insulator, which proved to be the greatest challenge of the whole project. It must be strong enough to support the upper 2/3 of the antenna without guying. I finally settled on building the insulator from PVC pipe reinforced with plexiglas™ panels and nylon cord, the whole thing held together with silicone rubber bathroom caulk and epoxy. I calculated the insulator's strength to be much greater than that of the aluminum tubing right above it. So, theoretically at least, the antenna should break at the tubing and not at the insulator.

By calculating stress values for the whole antenna, I found that if I used 1" steel pipe for the bottom 1/3 section and 1-1/4", 1", and 3/4" aluminum tubing for the 3-piece upper 2/3 section, the antenna would be strong enough to be self-

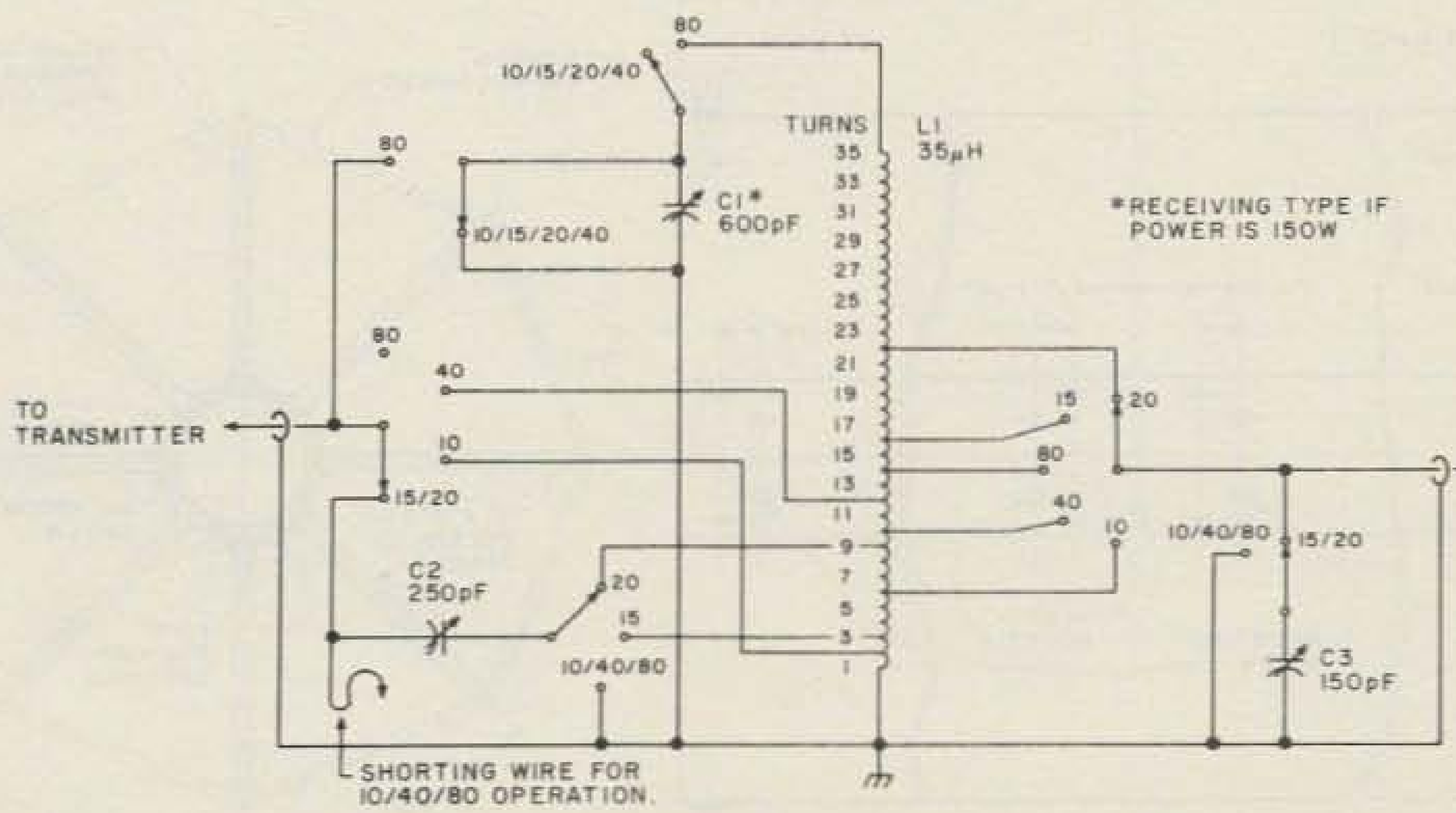

Fig. 4. Antenna tuning unit set for 20 meters. All air variables not in use are shorted and grounded.

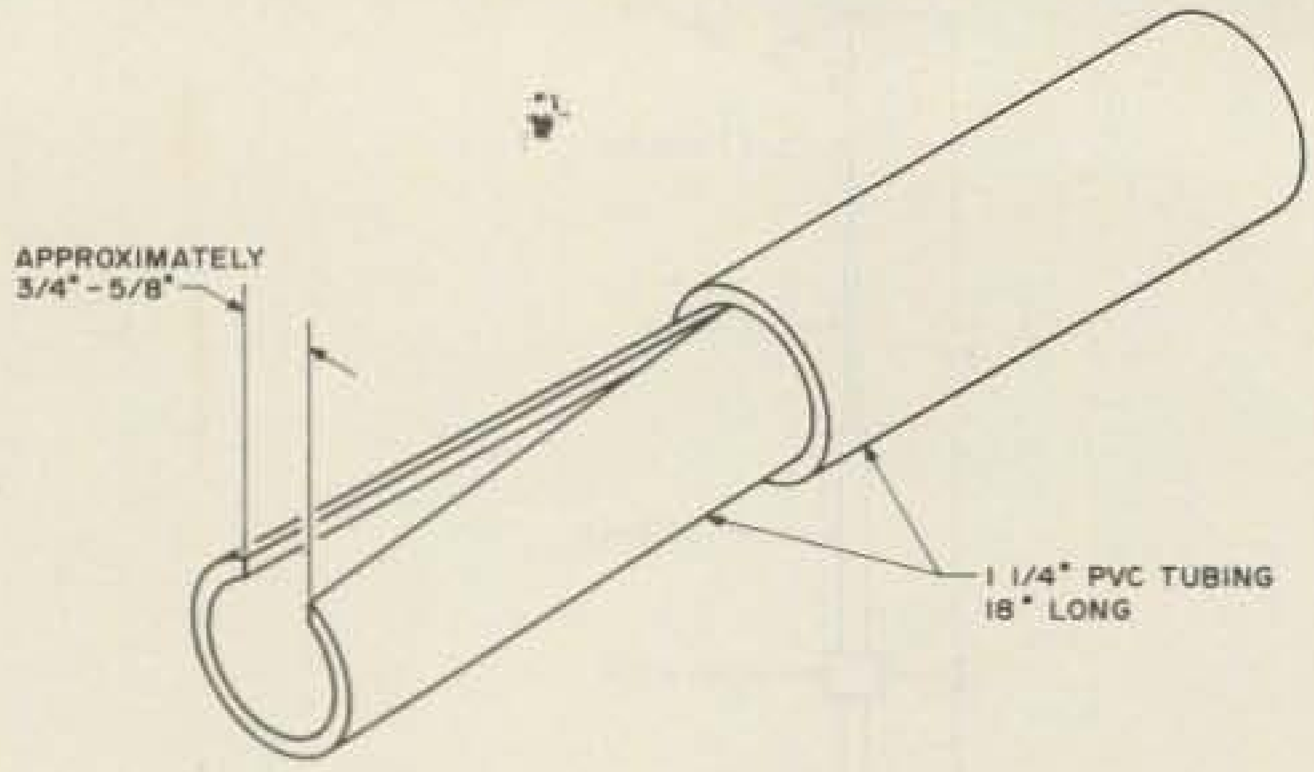

Fig. 5. Joining the two 1-1/4" PVC sections.

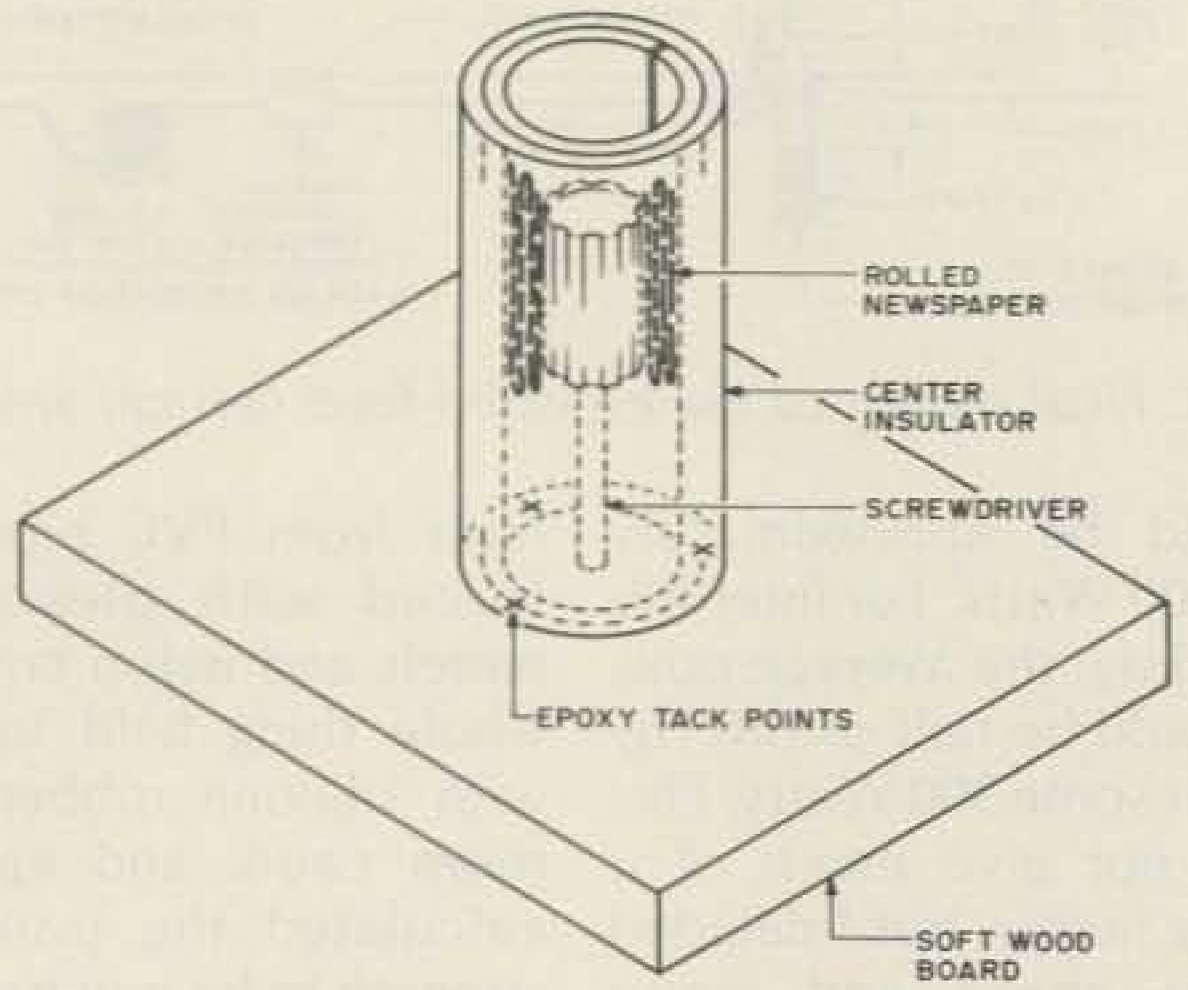

Fig. 6. Jig for the construction of the center insulator.

supporting. The weakest link would be the 1-1/4" aluminum tubing section. Moral support for this decision came from Capt. P. H. Lee's excellent book, *The Amateur Radio Vertical Antenna Handbook,* where he used this size tubing to construct his Mark II antenna.[5] He claimed that the antenna was flexible; it bent with a high wind and did not break.

The final design of this antenna is shown in Fig. 3, and the tuning unit is shown in Fig. 4.

Construction Procedure

The construction is started by the assembly of the center insulator. Fig. 5 shows how one piece is cut and inserted into the other piece. Use PVC pipe cement to bond the two pieces together.

Fig. 6 shows how an inexpensive jig can be constructed from a screwdriver and a piece of soft wood. This jig will hold the cemented PVC pipe in a vertical position to ease the task of cementing the plexiglas panels. The panels can be epoxied to the pipe first so that they will stay in place when applying the silicone rubber bathroom caulk.

Before cementing the plexiglas panels, insert the steel pipe and aluminum tubing into the PVC pipe to the dimensions shown in Fig. 8, i.e., to within 1/2" from each other, centered at the center of the insulator. Mark the radial direction on the pipe, aluminum tubing, and insulator. Drill holes 90° apart in the pipe and tubing for the mounting bolts, drilling through the PVC pipe. When drilling in pipe, *use a 1/4-20 tap drill* and enlarge the hole to 1/4" when the pipe is removed. The position of all holes is shown in Fig. 7. To avoid weakening the pipe, stagger the tap holes. This procedure will align all the holes and assist in the final assembly.

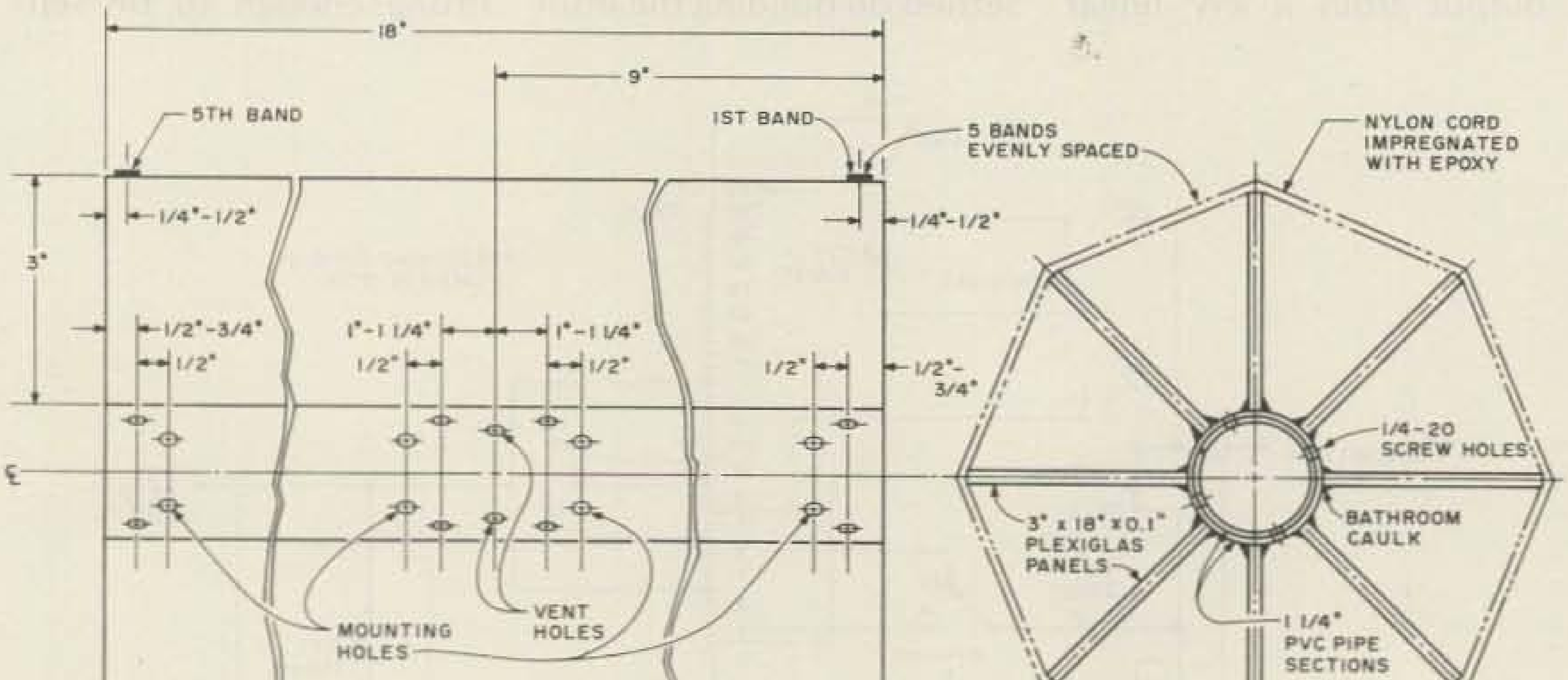

Fig. 7. Construction of the center insulator.

When the bathroom caulk has cured, wind five bands around the panels as shown in Fig. 7. Use nylon or dacron line approximately 1/8" in diameter and space the bands evenly. Epoxy the line for extra strength and to prevent it from unwinding. Drill the two vent holes between the panels in the center of the insulator. Build a little roof over the vent by using caulk. This will prevent moisture from seeping into the insulator.

The three sections of the aluminum tubing are assembled as shown in Fig 9. The bushing is made by cutting 6" from the smaller of the two pieces at the junction, splitting it and forcing it over the shortened piece.

The top hat is made by cutting a 3-foot length from aluminum clothesline, bending it in the center, and bolting it in place as shown in Fig. 10. After it is bolted in place, bend it until it is perpendicular to the tubing. After bending, cut it to the dimension shown (1'4") and spread the two wires until they are 90° apart. Install the top button and seal the whole area with bathroom caulk.

If possible, obtain a piece of 1" Schedule 40 pipe which is 15 feet long. If this cannot be obtained, use one 10-foot and one 5-foot section. Position the 5-foot section next to the insulator and join the two pieces together by using a 12-inch piece of 1-1/4" Schedule 40 pipe and 1/4-20 bolts. Use aluminum sheet between the pipes for a tight fit. Drill and tap the holes at this junction by following the same procedure as outlined previously when drilling holes in the center insulator. Drill one 7/16" hole approximately 4-5 feet from the bottom end of the pipe. This is the exit hole for the coaxial cable.

Cut a piece of RG-8 foam

coaxial cable 15 feet long. Strip one end as shown in Fig. 8. Allow sufficient length of shield to produce the slack. During assembly, the pipe and aluminum tubing will come together across the 1/2" gap forcing the coax down. The slack is needed to prevent bending or damaging the center conductor. Impregnate the center conductor and the shield with solder so that about 1/4" of soldered length will protrude from the silicone rubber caulk when applied. Apply silicone rubber caulk as shown in Fig. 8 to seal the cable from moisture.

Thread the cable from the insulator end to the 7/16" exit hole by using a length of wire taped to the cable. Exercise caution in taping the cable since the hole does not allow too much clearance for the RG-8 cable.

Fig. 11 shows the position of the three components prior to assembly. Use electrical tape and aluminum sheet wrapped around the tubing and the pipe as necessary to ensure a tight fit for the center insulator. Cut holes in them for the bolts to pass through and smooth all edges so that the center insulator slides smoothly over the aluminum tubing and the steel pipe.

Slide the center insulator over the aluminum tubing. Verify the markings which were made during the drilling to avoid hole alignment problems.

Attach the shield of the coaxial cable to the pipe first. To do it, drill and tap a 1/4-20 hole in the pipe about 1/2" from the end, as shown in Fig. 8. Screw a 1/4-20 bolt from the outside of the pipe. Secure the shield to the bolt inside the pipe with a nut. Tighten the nut. Cut the bolt flush with the outside of the pipe wall.

Bend one edge of aluminum tubing and drill a 10-32 clearance hole in the bent section, as shown in Fig. 8. Attach the center conductor to the tubing by using 10-32 hardware.

Slide the aluminum tubing until it butts against the pipe. If the slack in the shield is of correct length, the two pieces should butt without any problem. If they do not butt properly, more slack in the shield will be required.

With the two sections butted, slide the whole antenna until it rests against a wall or other stationary object. Slide the center insulator over the pipe until the mounting holes are in alignment. Secure the insulator to the pipe by using 1/4-20 × 1/2 bolts. Gently slide the aluminum tubing out of the insulator until the mounting holes are in alignment. Secure the insulator to the tubing using 1/4-20 × 2 bolts and nuts.

Install the antenna in a 1-1/2" pipe, 5 feet long, which is driven into the ground to a depth of 4-1/2 feet. Small stones are dropped into the pipe to limit the depth of insertion. Aluminum or hardware shims are used to hold the antenna in place.

A ground radial system is needed for optimum performance, especially on the 80- and 40-meter bands. I have five radials, each 33 feet long, and I plan to install eight more. As with every vertical antenna installation, a low ground resistance is necessary for good performance. A high ground resistance (few or no radials) results in high power losses because the ground resistance is in series with the radiation resistance of the antenna.

For this installation, I attached the ground radials to the 1-1/2" buried pipe. I grounded the antenna to the pipe by using a 1/2" × 1/8" aluminum grounding strap.

Tuning Unit Construction

The schematic of the tuning unit is shown in Fig. 4.

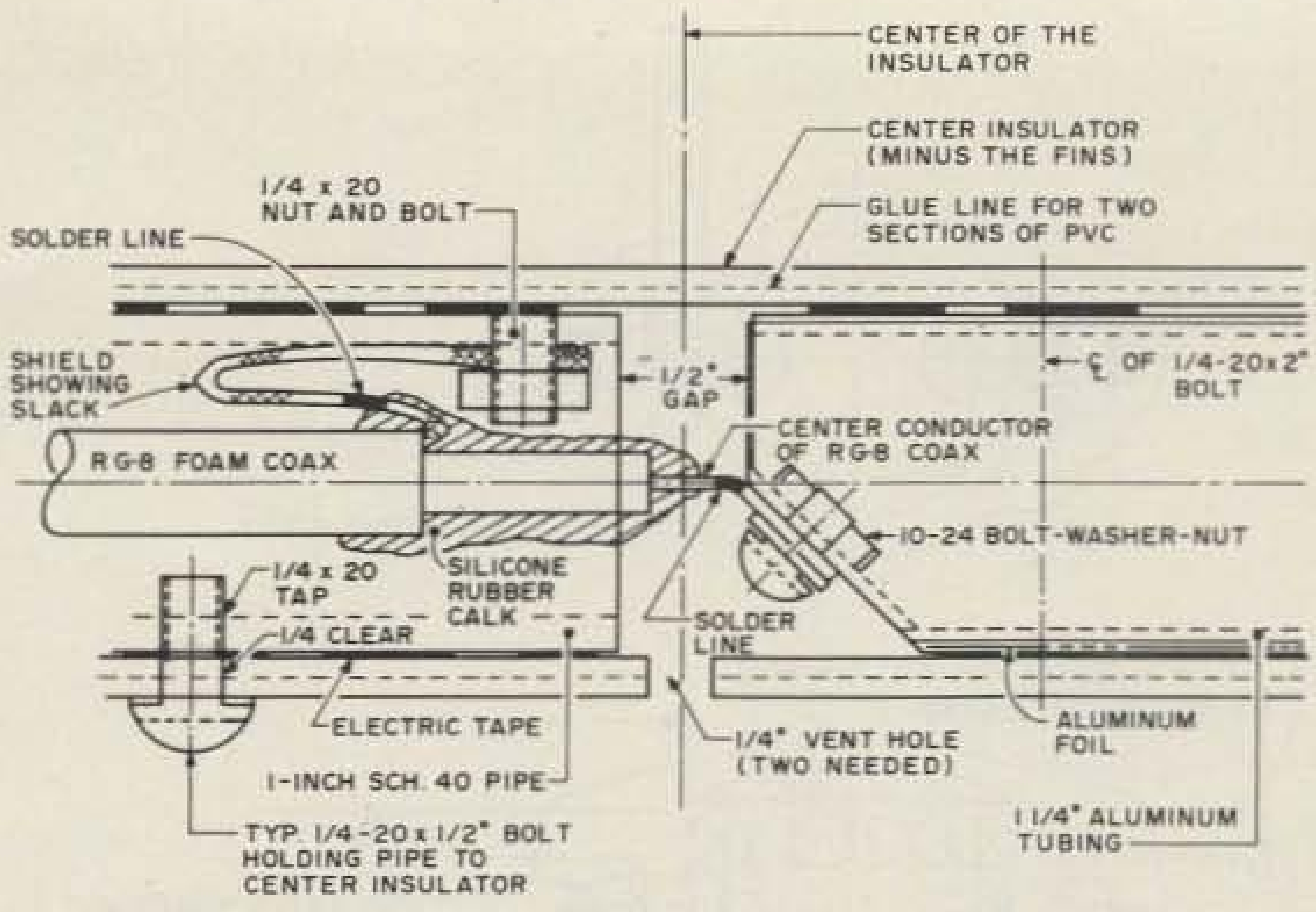

Fig. 8. Locations of the pipe and tubing within the center insulator.

The unit is installed next to the antenna, but not grounded to it. It is grounded only to the shield of the coaxial cable.

I constructed my tuning unit on a piece of plexiglas 7-1/2" × 16-1/2" and mounted it inside a watertight cabinet. Since I had enough air-variable capacitors in my junk box, I decided to be extravagant and use separate C2 and C3 air variables for the 15-meter and 20-meter bands.

One word of encouragement: The construction of this unit is not complicated. The cost to build it need not be high. I obtained all the parts and the cabinet for about six to seven dollars at two hamfests held in my local area. The real bargain find was an old Army surplus tuning unit which was priced at $5.00. This unit yielded two air variables, the coil, and the enclosure. To those of you reading this article who have not been to a hamfest, my advice is to go to one! It is lots of fun plus being a place for some real bargains.

Once the tuning unit is built, connect it to the coax feeding the antenna and to the transceiver placed next to the unit. Follow the procedure below to obtain tap points for your coil.

Tuning Procedure Using Swr Meter

(1) Connect the swr meter in the line between the transceiver and a dummy load.

(2) Tune the transceiver as usual for maximum output on the 80-meter band. Adjust the swr meter sensitivity for a full-scale forward power indication.

(3) Do not change any of the transceiver or swr meter settings. Switch the swr meter to read reflected power.

(4) Disconnect the dummy load and connect the tuning unit in its place.

(5) Using the turns ratio in

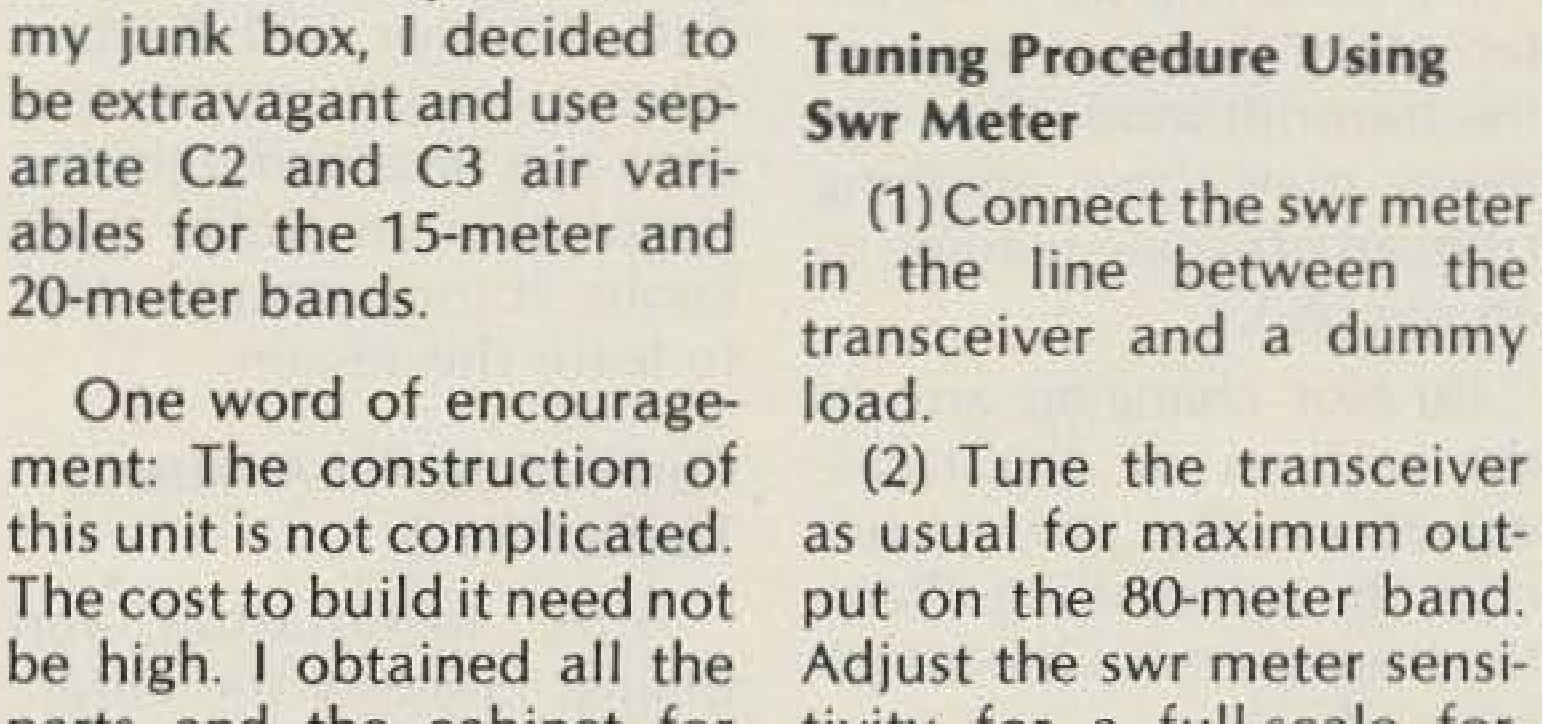

Fig. 9. Assembly of the aluminum tubing sections.

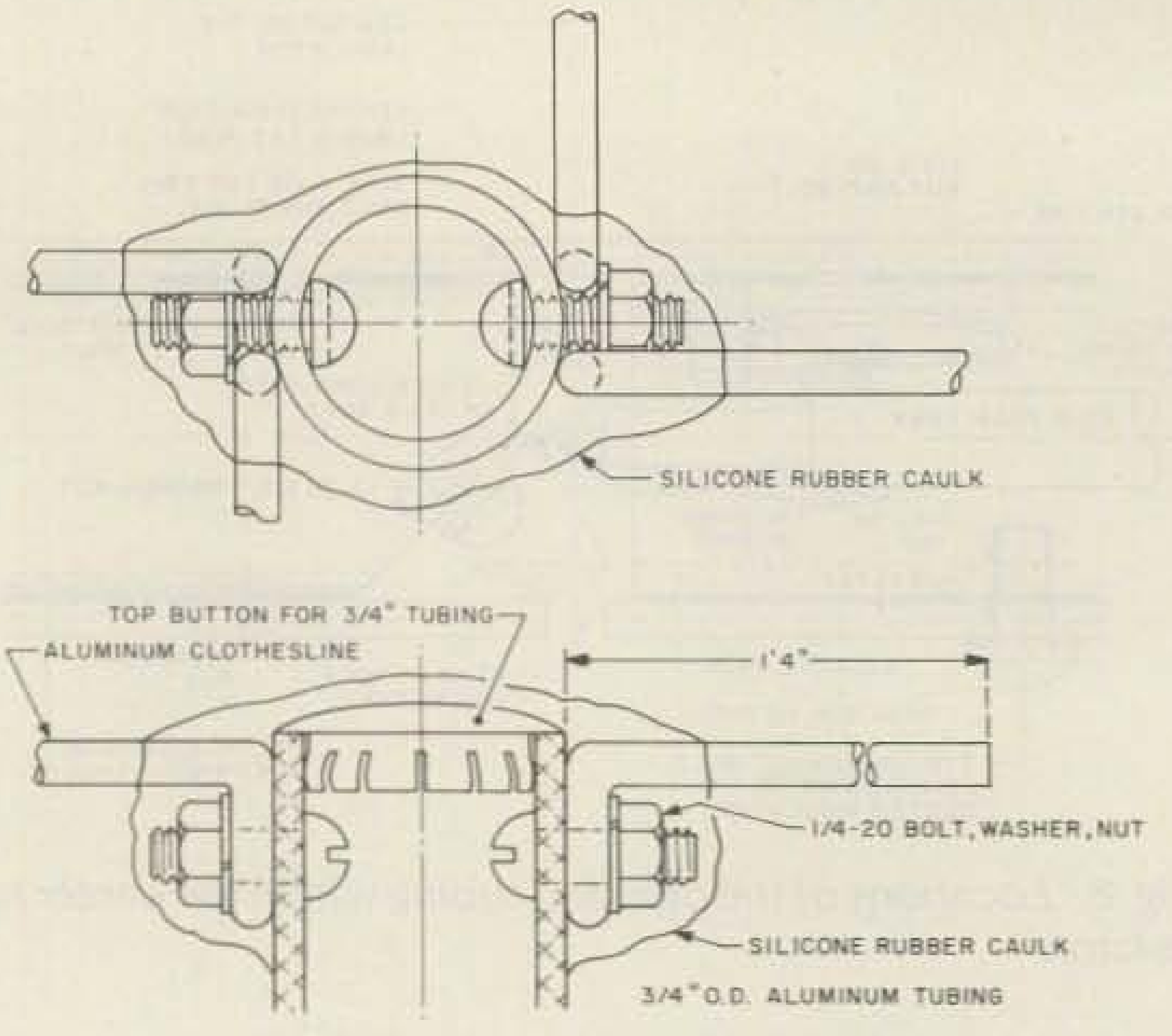

Fig. 10. Top-hat assembly.

Fig. 4 as a guide, connect the appropriate wires to the coil using alligator clips or equivalent.

(6) Position all tuning unit switches to 80 meters and adjust all air variables to *minimum* capacitance.

(7) Watching the swr meter, place the transceiver in the transmit mode. The swr meter may show anything from an off-scale reading to an swr of 1:1.

(8) Not changing any of the settings on the transceiver or the swr meter, note the swr reading. Place the transceiver in the standby mode.

(9) If the swr was high, adjust the taps on the coil and repeat steps 7 and 8. If the swr was low (swr meter deflection is 1/2-2/3 scale, equivalent to an swr of about 3:1 to 5:1), leave the taps alone and adjust the air variable for an swr of 1.3:1 or lower.

(10) Repeat steps 7 to 9 until an swr of 1.3:1 or lower is obtained. Record all settings for future reference.

(11) Repeat this procedure for the other bands.

The procedure is designed to obtain the best possible match by adjusting the turns on the coil first. Once this is accomplished, air variables are used to reduce the swr still further. Always adjust one component at a time and fight the temptation to tinker with knobs. It took me two days to learn this lesson.

Connecting the Antenna To the Shack

After installation and tuning, connect the antenna to the shack by using buried RG-8 coaxial cable. Install the lightning protection system as shown in Fig. 3. It consists of a coaxial lightning arrestor grounded to a 5'-6' ground rod, followed by the turns in the coax. Tape the arrestor well with electrical tape to prevent moisture damage.

Performance

The theoretical performance calculations were hammered out with N9CR during various coffee breaks. He has a newly installed three-element tribander atop a 60' tower. We chose to compare the relative merits of the elevated-feed vertical antenna to those of the beam 60 feet in the air.

Theoretical data for this comparison came from *The ARRL Antenna Book* and and P. H. Lee's book, *The Amateur Radio Vertical Antenna Handbook.*[6,7] The summary is presented below. We chose the 20-meter band for this comparison.

A three-element beam 1λ above ground has a vertical pattern consisting of two lobes. Only the lower lobe is good for DX. It has a horizontal beamwidth of about 60° (−3-dB points) and a vertical beam width of about 15° in the lower of the two lobes. Judging by the published patterns, we assumed that the power going into the antenna is divided equally between the two vertical lobes.

The beamwidth of the elevated-feed vertical antenna on 20 meters is approximately 20° in the vertical plane. Since it is non-directional, the horizontal beamwidth is 360°.

For DX operation, the spherical area illuminated by the beam is 60° × 15° = 900 "square degrees." The spherical area illuminated by the elevated-feed antenna is 20° × 360° = 7200 "square degrees." The power gain of the beam relative to that of the elevated-feed antenna can be calculated theoretically as

$$\text{Gain (dB)} = 10 \log P_1/P_2$$
$$10 \log 7200/900$$
9.03 dB over elevated feed

Because only half of the power (3 dB down) goes into the "useful lobe," the actual gain that the beam realizes over the elevated-feed vertical antenna is 9.03 dB −3.0 dB = 6.03 dB, or 1 S-unit.

Jokingly, we both agreed that although N9CR's tribander at 60 feet had a gain of 6 dB over my elevated-feed vertical, I held a 13.3 dB "gain advantage" in cost.

On the air, the antenna performed beautifully for DX on 28 MHz and 21 MHz where the radiation is at low vertical angles. On 14 MHz, the antenna performed very well over the United States and Canada, and fairly well for DX. On 7 MHz and 3.5 MHz, the antenna lays down a strong ground wave; I had very good signal reports from stations 30 to 40 miles away. Many fine 80- and 40-meter QSOs were also had with stations as far as 800 miles away.

Conclusion

I wish to express my thanks to K9CGD to whom this project was first presented and who encouraged me to proceed with it. Thanks are also due N9CR who nursed the project from the beginning to the end and who, having tried the antenna on the air, pronounced that "...it worked as expected." I feel that the elevated-feed principle has much to offer to the amateur radio operator. In fact, I like this antenna so much that I am planning to optimize performance on 20 and 40 meters by designing and building one which will be 66 feet tall. But that's another project. ■

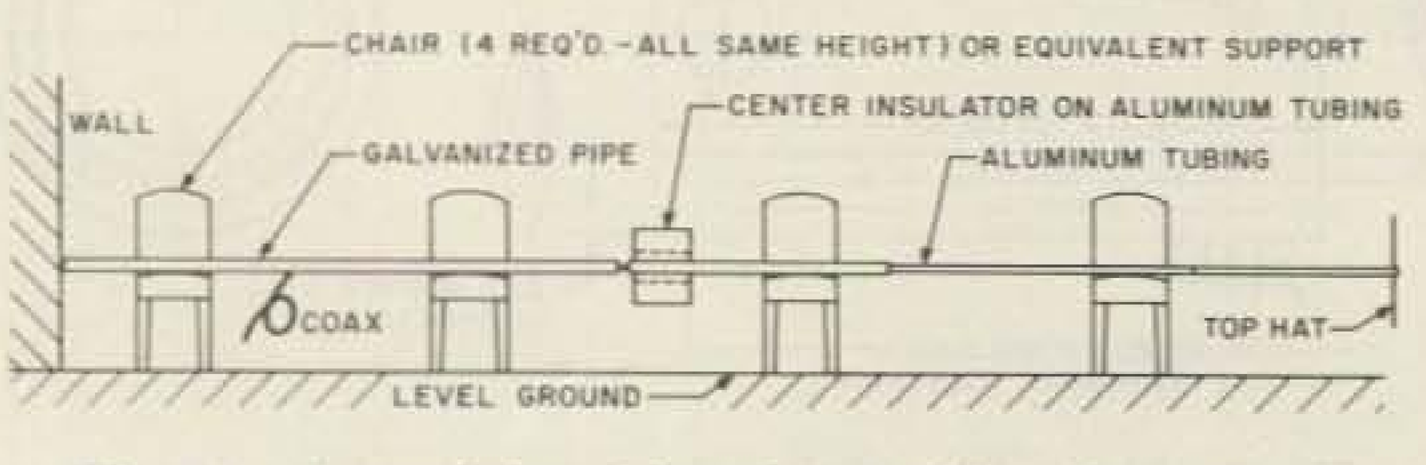

Fig. 11. Assembly of the elevated-feed antenna.

References

1. *Amateur Radio Techniques*, an RSGB Publication, Fifth Edition, 1974, pp. 233-234.
2. *Ibid.*, p. 233.
3. *The ARRL Antenna Book*, 1968 edition, pp. 32-33.
4. *Ibid.*, p. 100.
5. *The Amateur Radio Vertical Antenna Handbook*, Capt. Paul H. Lee, USNR, K6TS, Cowan Publishing Corporation, 1974 edition, p. 94.
6. *The ARRL Antenna Book*, pp. 46-48 and 56-58.
7. *The Amateur Radio Vertical Antenna Handbook*, pp. 11-13 and 18-19.