Monoband Yagi for 20 Meters

More dBs for the buck.

by Kenneth C. Kemski AB4GX

Like many amateurs, I live in a residential neighborhood where local sentiments do not favor large antenna arrays. Among my favorite operations, however, is hunting DX on 20 meters. This requires attempting to be heard through the pile-ups that develop around almost any semi-rare station that fires up its rig.

There would appear to be three distinct means of achieving the end of "pile-up crashing": blind luck; shouting your call hundreds of times, despite who is talking or listening (much to the consternation of everyone involved); or having an effective signal that allows you to "get in-and-out" within a few calls.

The chain between your microphone and the desired DX station's ears may include many links, and among the most important (after professional protocol) is the antenna. It is difficult to construct an antenna that affords good gain, directional performance, and usable bandwidth in a small package that won't antagonize the neighbors!

My results with semi-inconspicuous verticals, inverted vees and slopers were somewhat discouraging. It appears that one can develop an S-5 to S-6 signal anywhere in the world where propagation exists, and enjoy many a fine QSO. Unfortunately, pile-ups of any size became primarily a means of killing time until the DX station went QRT for the day.

I finally decided to attempt to design a reduced size monoband yagi that would give me a "fighting chance" under adverse conditions (. . . most DX contacts).

The criteria were to obtain: the smallest size possible, 10 dBi forward gain, usable front-to-back and front-to-side ratios, and the ability to withstand Florida's high winds. The result is the antenna described here.

I began to design by purchasing an antenna analysis program, based on the successful Minninec format. It is written and distributed by W7EL, and called "ELNEC." This PC-based program is an absolutely fine undertaking, and is worth many times the asking price. (See the ELNEC review in the January 1991 issue of *73 Amateur Radio Today*.) A detailed description of this program would require an article in its own right. Suffice it to say that I fed my ideas for this antenna into ELNEC over a two-month period, scrutinized the results, and then assembled and tested the final design. I achieved almost total agreement between ELNEC's analyses and real-world performance; for example, the calculated element lengths were within 3/8″ of final tuning!

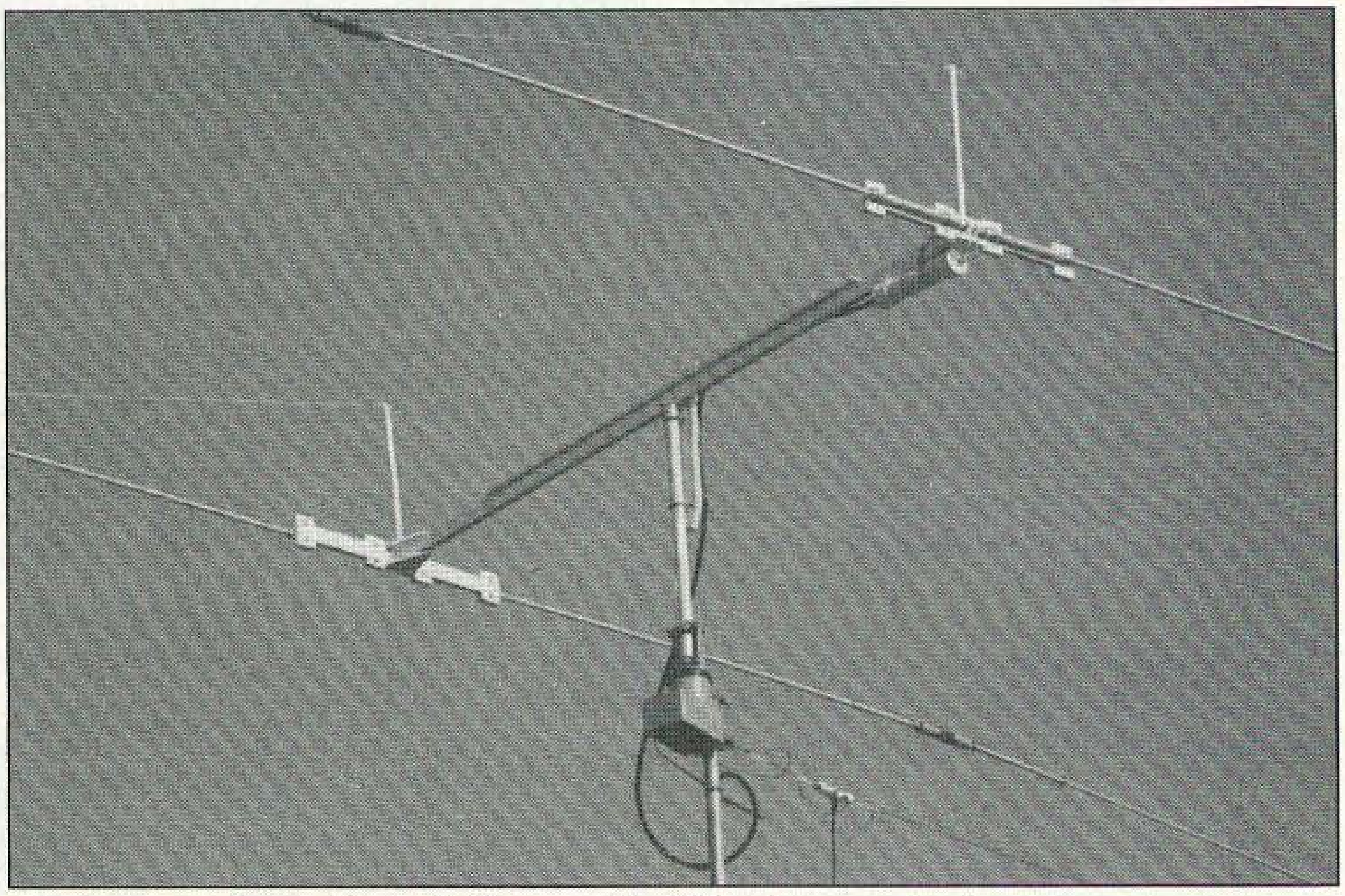

Photo A. The completed 20 meter mono-bander.

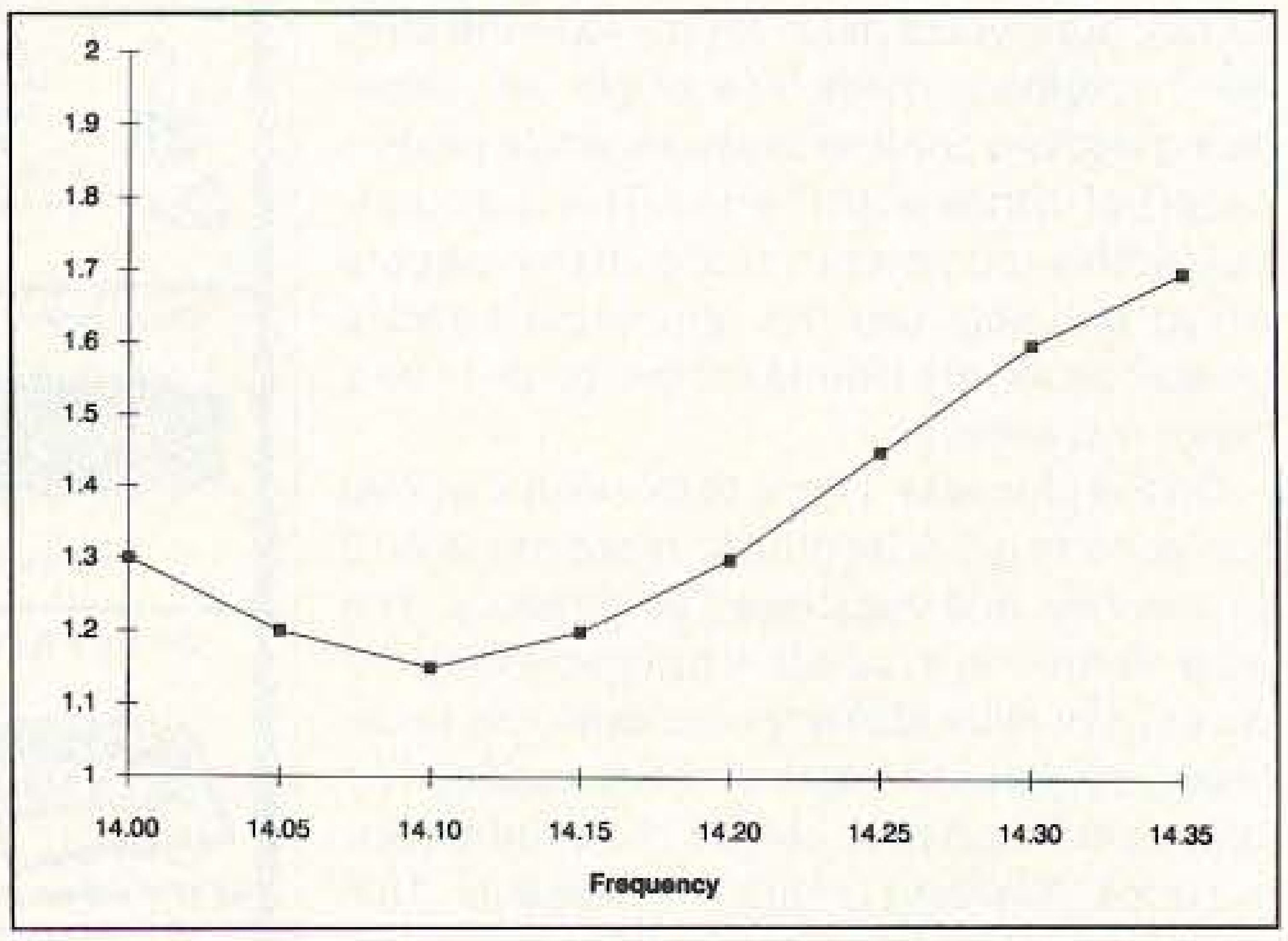

Figure 1. Measured SWR of the 20m shortened yagi.

Design Parameters

The main considerations and variables included the following important areas:

1. **Gain** This was paramount in importance, because they can't hear you if they can't hear you . . . Every available parameter was "tweaked" for maximum forward gain commensurate within the SWR and bandwidth constraints. The result is +10 dBi of forward gain at the frequency of interest, increasing to +11 dBi in the general portion of the band (albeit with reduced front-to-back) and decreasing to +9 dBi in the CW portion of the band. (See Figure 2.)

2. **SWR** An electrically-shortened antenna usually has low radiation resistance and requires a matching network of some type. I watched gain while decreasing the element spacing, at the same time varying reflector tuning and other parameters. I found I could match this antenna directly to 50 ohm coax using only a 1:1 wideband current balun. The balun was used to eliminate radiation from the transmission line and preserve the calculated patterns. I would have incorporated a gamma match if it would have helped, but

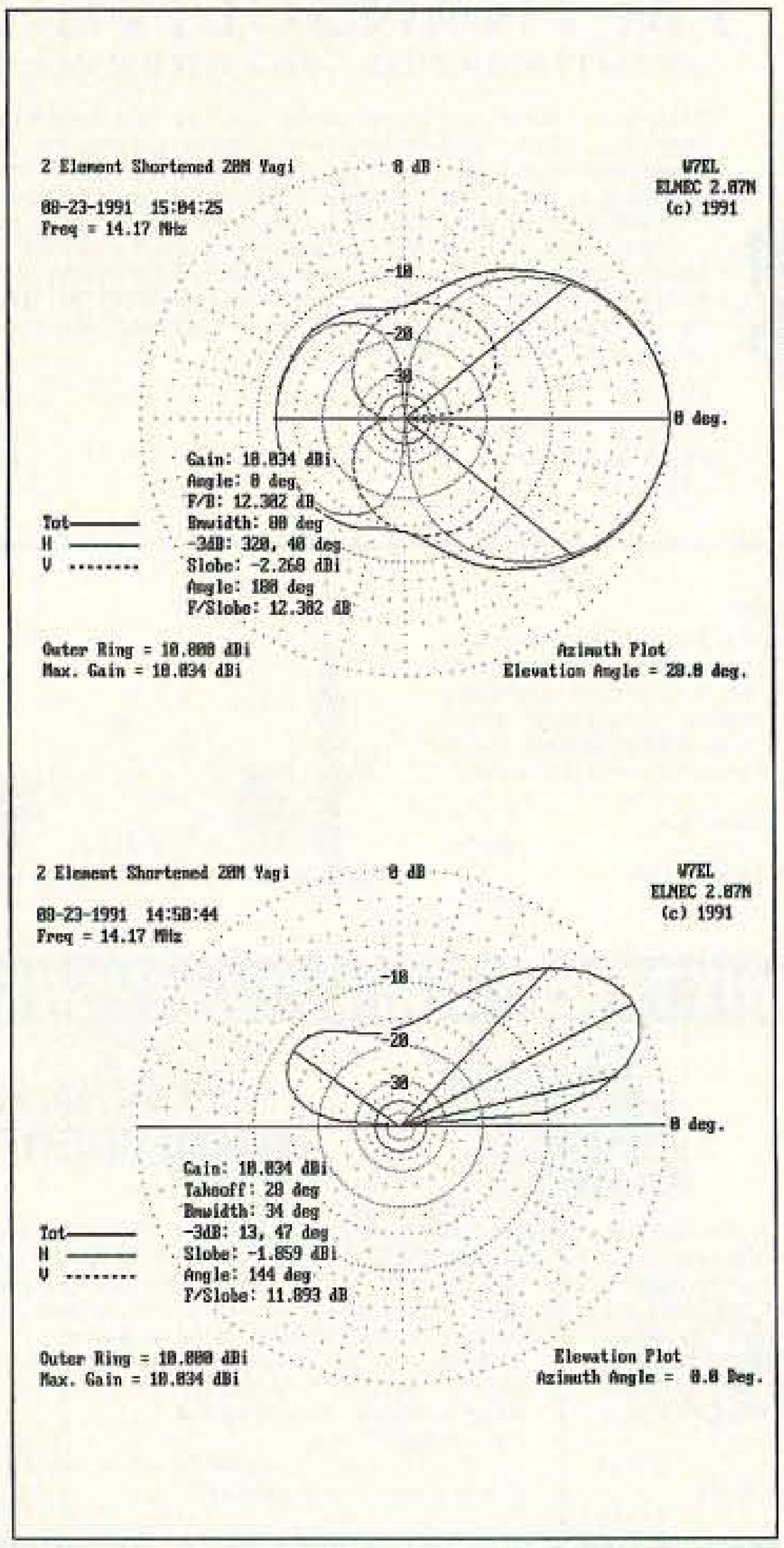

Figure 2. a) Azimuth plot of the yagi using the ELNEC program. b) The elevation plot.

believe me, this antenna is a good match to 52 ohm coax!

3. **Q (Bandwidth)** An electrically-shortened antenna also exhibits higher Q than its full-sized counterpart and this means less usable bandwidth. I wanted optimum performance, primarily within the frequency range of 14.150 to 14.225 MHz (where I hear much of the DX I'm interested in). I received an unexpected bonus when I modeled the antenna, and then constructed and tested it. Analysis showed a far better bandwidth than I had sought, and the finished antenna produced a full 350 kHz bandwidth with low SWR when measured at the transmitter end of the feedline.

Subsequent remodeling and investigation suggests that the additional bandwidth results because of two reasons: Loading coil Q is lower than originally modeled (fortuitous because of the "low-profile low-wind-load" form factor I had chosen); and attenuation exists in the 50 feet of RG-8 coax needed to bring the antenna into the shack. You'll find that the attenuation of a random run of coax will yield lower SWR measurements at the transmitter than that measured directly at the antenna, and this serves to "pull down the end points" of the SWR curve. Figure 1 shows the broadband nature of this reduced size antenna.

The coax losses are sufficiently low as to be negligible for two reasons: The losses occur only at the edges of the frequency band of interest; and a tuner or matching network at the antenna also would introduce losses, and they would not be confined to band edges.

4. **Pattern** We'd all like to offer a "laser beam" to the world when we transmit, but I settled for reasonable front-to-back and front-to-side ratios with this antenna because of the constraints placed upon it. The front-to-back ratio varies from 12 to 18 dB, or 2 to 3 S-units in both calculated and on-the-air tests. With the Pacific to my back when beaming Europe or Africa, and the Atlantic at the flank when beaming the South Pacific and points west, it has proven to be a good choice. For stations at a reasonable distance, a distinct "null" appears off the sides of the antenna, probably due to the horizontally polarized signals predominating. (See Figure 2.) I'll admit that I placed pattern after gain when optimizing this yagi, but I have no difficulty determining when I point at a station (or its propagation path). This is very unlike a commercial "mini" I had occasion to operate from a friend's shack a few years ago, where it seemed we were turning a vertical! This antenna does have a usable pattern.

Completed Design

Personal design constraint called for a total of 20′ element length, a spacing not to exceed 8′ (two elements), and maximum height above ground of 33′. The total antenna wind load and weight allow the use of an unobtrusive guyed push-up pole. The antenna that resulted from a few months of modeling on the computer has the following measured characteristics: element length = 20′; boom length = 6′; forward gain = 9+ dBi; F/S, F/B = >12 dB; and full band coverage with less than 1.7:1 VSWR.

Compared to its isotropic counterpart and using 1,200 watts input, this antenna provides an average of 12,000 watts ERP in the direction it is pointed. After examining the performance of many commonly used "antennas" on my computer, this, I can assure you, is a very strong signal.

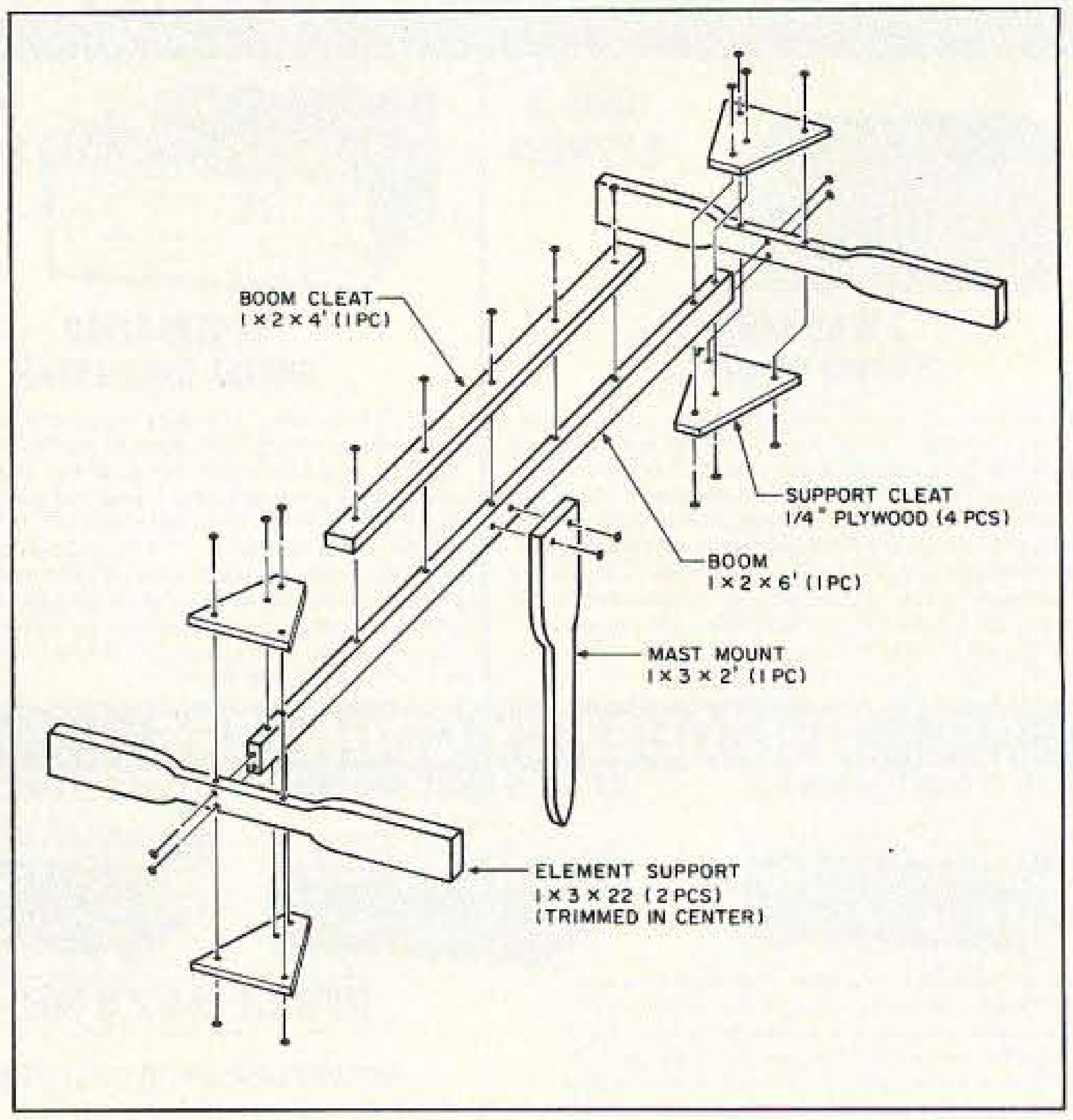

Figure 3. Boom assembly.

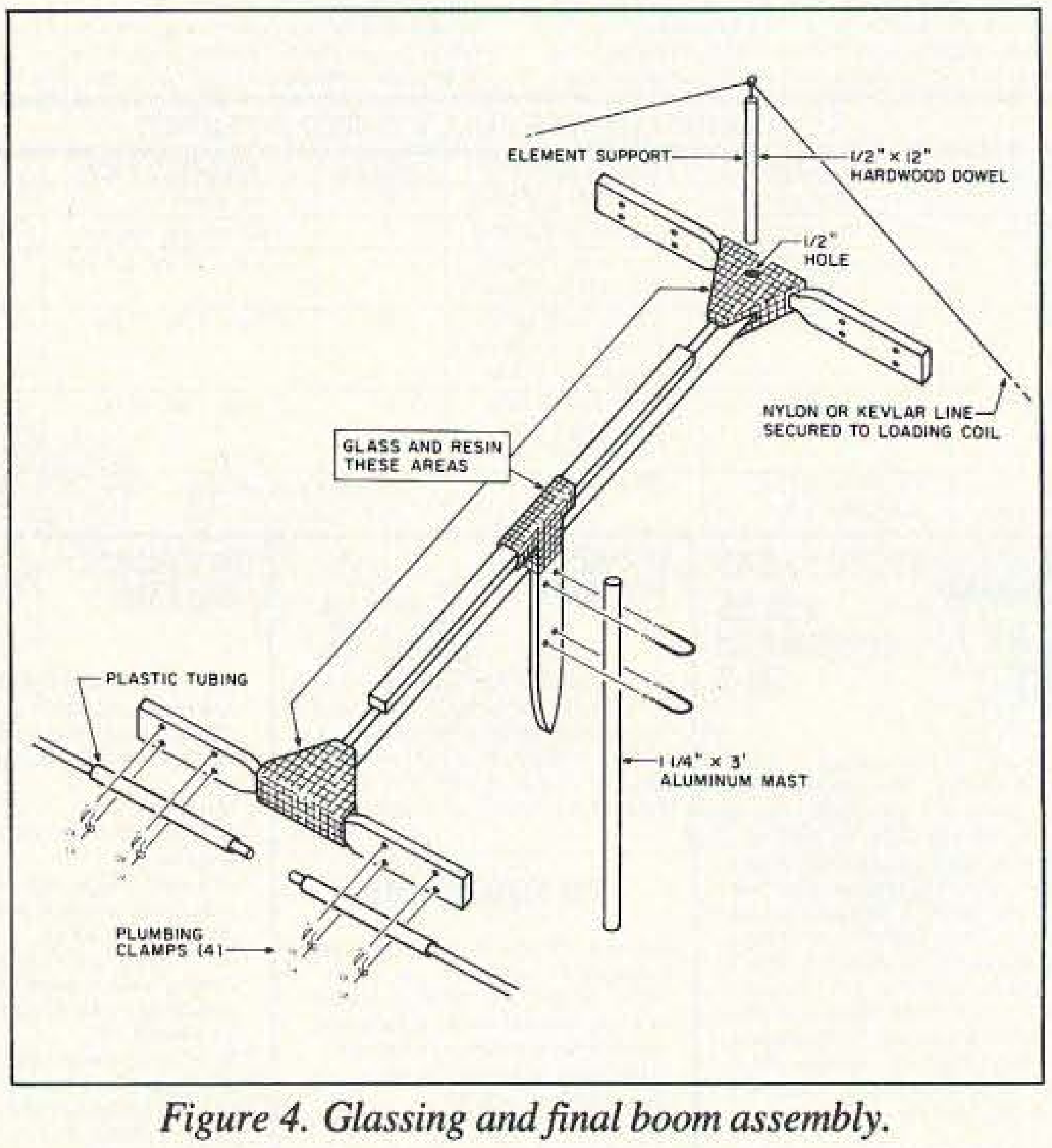

Figure 4. Glassing and final boom assembly.

Construction

Since the antenna was to be as unobtrusive as possible, I chose a wood and aluminum design for maximum structural strength commensurate with small size. I used a wooden boom (common fir) and reinforced it with fiberglass cloth and resin. This allows a good degree of flexibility, strength, and light weight for "pole" mounting.

I constructed the elements from 1/2″ and 3/8″ aluminum tubing, available at many hardware stores in 6′ lengths. These diameters are very small as common yagi elements go and have survived severe Florida winds without problem. This is probably because of the elasticity or "springiness" of the wooden boom elements. You cannot appreciate the small "willowy" nature of this antenna until you construct it.

Construction begins with the boom itself, shown in Figure 3. It is not wholly necessary to glass the joints, but you assure long-term reliability if you do. Kits for glassing are available from your local department stores (such as K-Mart) or automotive shops. These inexpensive kits contain enough fiberglass cloth and resin to complete this antenna, and a few more besides! After glassing the stress points shown in Figure 4, I used automotive primer and white automotive enamel (obtained where I bought the fiberglass kit) to spray the entire assembly for weather protection and unobtrusive appearance.

After the boom has cured, drill holes for the element mounting clamps, which are common plumbing clamps. Secure the 1/2"-diameter by 5'-long aluminum tubing to the element holders, also shown in Figure 4, spacing the ends of the tubing about 1" apart. Notice that I isolated the elements further from the boom mounts by slipping clear plastic tubing over the ends (also obtained from my local hardware store). You might wonder why I would bother to isolate elements when "plumber's delight" construction predominates in yagi construction, and I already had wooden insulating supports. Take nothing for granted, and KISS (keep it simple, stupid) are my mottos. I had analyzed the antenna as a set of free space conductors and that is what I wanted to build!

Connect the inside ends of the reflector with #12 wire and a pair of solder lugs screwed into the 1/2" tubing, shown in Figure 6. Be sure to weatherize these connections as well.

You can strap the Radio Works 1:1 balun to the boom near the driven element using one or two large stainless steel hose clamps. Connect the unbalanced output of the balun to the driven element ends, again using #12 copper wire, solder lugs, and self-tapping screws affixed to the 1/2" tubing. Be sure to weatherize these connections.

At this point, you have assembled the antenna as far as it can be and still fit in a normal garage. Subsequent assembly must be done outdoors, presumably on the day you will erect it.

Wind the loading coils on 1" wooden dowels, a total of 23 turns of #16 enameled wire spaced over 2.5 inches, for 4.2 µH of inductance, shown in Figure 5. Start by cutting a 1" wooden dowel into four 6.5" lengths, and then drilling a 3/8" hole into the ends of each dowel to a depth of two inches. Be careful to center the hole and keep the drill bit straight as it enters the dowel. A drill press and vise make the job easy.

After drilling the dowels, cut eight 5"-long pieces from a section of 3/8" solid aluminum rod. Mix up some "two-hour" epoxy, and after roughing one end of the rods with sandpaper, coat the rough end of each rod and insert it into the dowel until fully seated. Continue until all four dowels have 3/8" aluminum mountings at either end. This technique yields low profile, strong coil forms that you can easily attach to 1/2" tubing with hose clamps.

I used stainless screws and solder lugs, shown in Figure 5, to secure an electrical connection to the aluminum rods. I drilled small pilot holes through the wooden dowels at each end, continuing until the hole progressed into the rod. Wind the coils between the solder lugs and secure by soldering each end to its respective lug. To help in producing

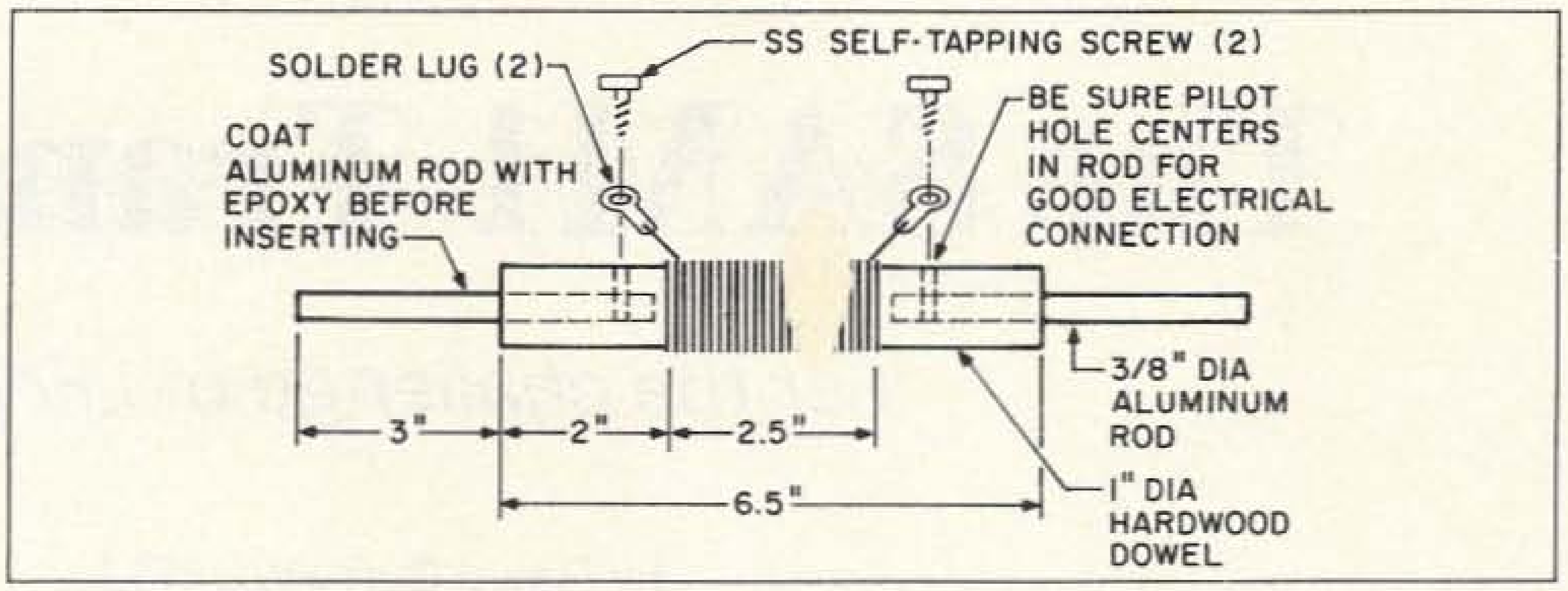

Figure 5. Loading coil assembly.

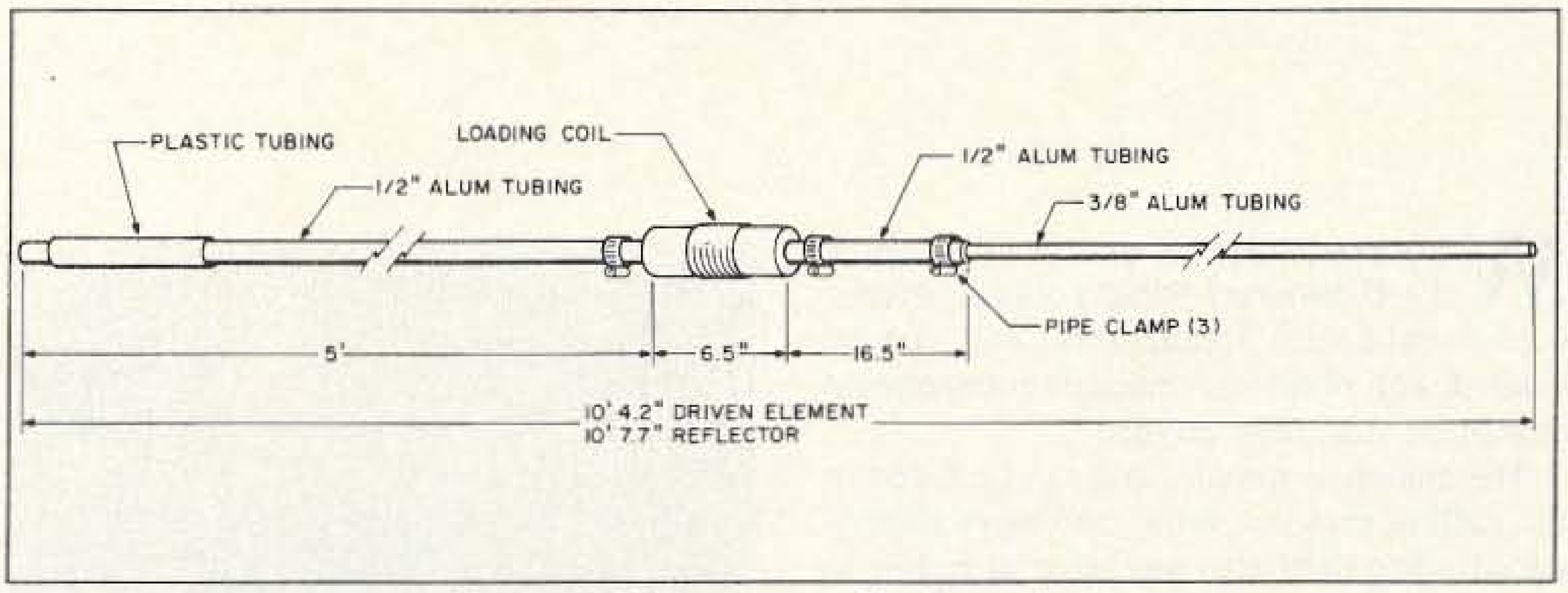

Figure 6. Element assembly (times four).

a uniformly wound coil, I used masking tape to secure the windings while I manually adjusted turns spacing with a thumbnail. This is very easy to do, and will only take a few minutes for all four coils. After the spacing looked uniform, I spread four thin beads of fast-curing epoxy down the length of each coil. I spaced the beads 90 degrees apart (the coils resembled B&W units at this point) and removed the masking tape when the epoxy cured.

The coil assembly must be weatherized, so I used 1-1/8" Teflon™ heatshrink over the entire length of the wooden dowels, and then sealed the ends with urethane. Alternatively, you can spray or brush the weather-resistant coating of your choice over the coil assemblies, making sure to seal the lugs and screws. The result will be loading coils that should last for a very long time.

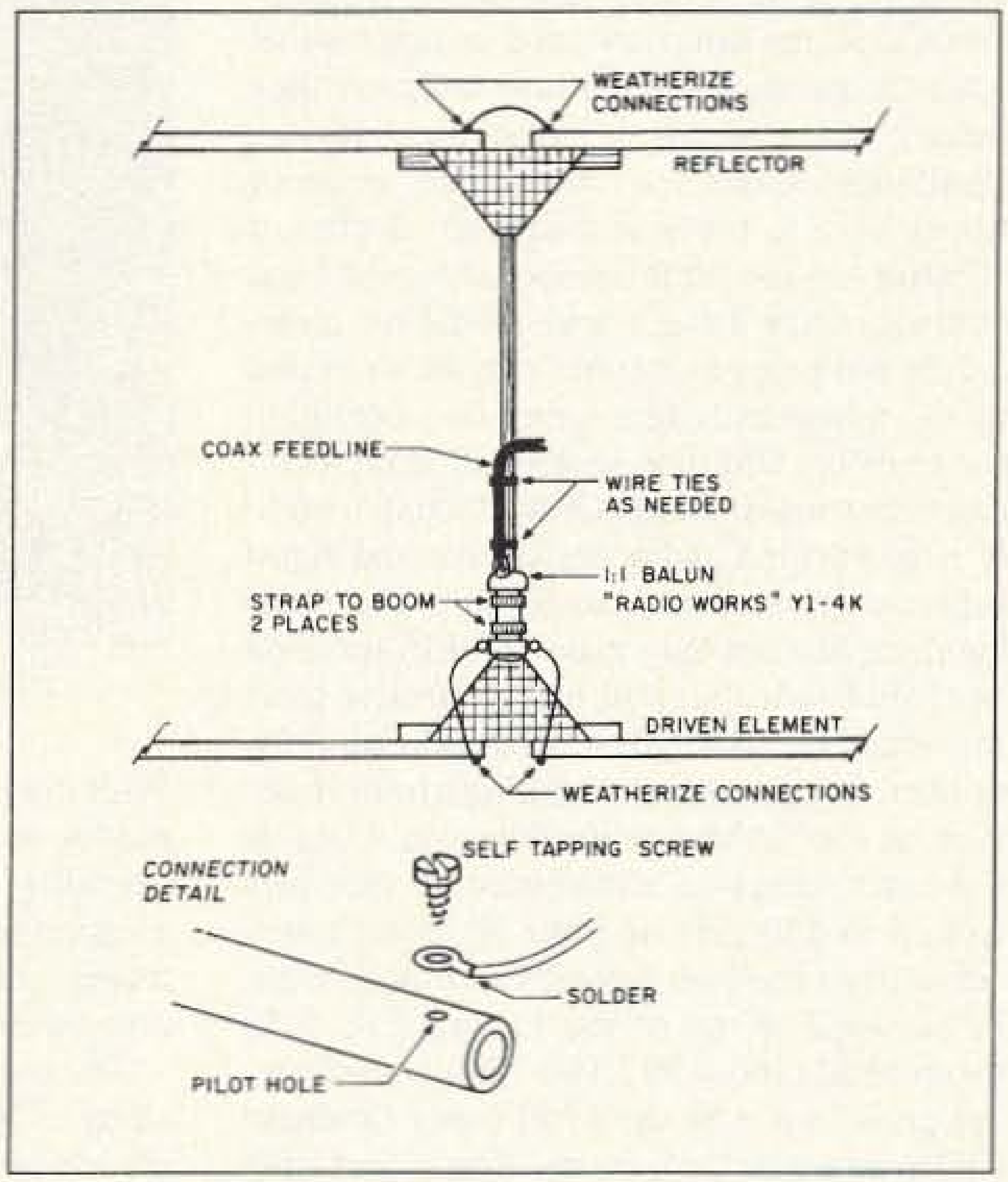

Figure 7. Final wiring.

Assemble the antenna elements by following the diagram in Figure 6. I used stainless steel hose clamps, but you can screw the element segments together, being sure to leave the four 3/8" end segments adjustable for tuning purposes.

Tuning

With the antenna lifted to the top of an 8' to 10' ladder, and using your rig at very low power (please don't cause QRM), simply tune the driven element to resonance at the center of your primary operating frequency. Adjust the reflector for a length that is 3.5" greater than the driven element on each side, or 7" longer overall. If you use the MFJ SWR Analyzer as I did, you can play around a bit with no fear of causing QRM. Repeat the process one more time and then recheck after raising the antenna to its final height. You can see from my SWR chart that I missed by a hint because of impatience. The antenna is usable over the entire band as tuned, and the high frequency side of the SWR chart does offer the highest forward gain . . . (excuses, excuses).

Antenna Mounting

To install the antenna, I used a 40' four-section push-up pole, a wall-mounting bracket, and a TV antenna rotor, all obtained from

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significant amount of resistance, and R41 compensates for this.

Some meters can measure up to 300 ohms of internal resistance, and you can calibrate a meter of this type simply by monitoring the current across R28 with a VOM or digital multimeter and turning R41 so the current on the meter will be the same as the current across R28. This concludes the bias adjustment of the SAM1.

Unground point TR and connect point "E" to the RF terminal on your HF transceiver. Zero beat the local oscillator on the SAM1 by tuning your HF transceiver to 3.5 MHz and rotating C14. If you own a calibrated frequency counter, you can check the frequency of the local oscillator at the output of Q3, or across C12 or L4. Make sure your transceiver is calibrated to the internal oscillator most modern HF transceivers are equipped with. If your transceiver has one, turn the oscillator on and zero beat the two signals, listening in the AM mode.

Checking Connections

With all connections to the SAM1 completed, check to make sure the points on the SAM1 are going to their correct places on the transceiver and antenna. Apply power and again listen to make sure you heard relay K3 kick over. Your HF transceiver will operate just as it would on any amateur band, along with any controls you wish to use to improve the reception or transmission within the 1750 meter band. The readout on the analog dial or digital display is simple to read: Ignore the 3.5 MHz; read only the kHz readout.

For example, let's say you're working an SSB station on 183 kHz. What would the readout be on your transceiver? Simple: 3.683 MHz; 3.683 - 3.5 = 183 kHz! Shortly you will become accustomed to ignoring the 3.5 MHz and the fact that your HF transceiver has been transformed into a complete LF/VLF station.

Make extra sure that the TR point on the SAM1 board is connected to the external relay port on your HF transceiver so the SAM1 will automatically follow the transceiver going from receive to transmit. Check this by placing the transceiver in the send or key-down (transmit) mode, but don't let any RF leave the transceiver.

Keep all carrier and mike controls on the transceiver to a minimum! Both relays (K1 and 2) on the SAM1 should key over. If you do not hear this, your wiring on the TR line is incorrect. Point TR must be grounded during transmit mode. If all is well and the relays key over, you're ready to check the transmitter half of the SAM1. Be sure to connect a *resonant* 1750 meter antenna to point "C"on the SAM1, or a 50 ohm, 2 watt load resistor as a termination. With both the transceiver and transverter in the transmit mode, send a low-level carrier of approximately 10 watts on the transceiver anywhere between 3.66 to 3.69 MHz (160 to 190 kHz), the legal band limits of the 1750 meter band.

Check the PA current of the SAM1 as discussed previously. The legal input power for continuous duty or CW to the PA is 1 watt. Not much, but surprisingly effective! Hundreds of miles have been successfully and regularly worked on such low power, which adds to the challenge of the 1750 meter band. When operating SSB, however, 2.8 watts peak-to-peak is allowable, and the transverter can handle this easily.

The bias current to Q7 is adjusted to a class AB condition (15 mA) to accomodate SSB operation. The drive level from the HF transceiver controls the RF output of the SAM1, with only a small amount (10 watts) required for legal output on 1750 meters. With too much power or a too-high bias, transistor Q7 can go into thermal runaway. The bias will naturally increase as the temperature of Q7 increases, so don't be concerned about this. Temperature-tracking diodes D2 and 3 are help minimize this condition.

Because of their continuous duty operation, digital modes such as RTTY and AMTOR require that you keep the drive to the SAM1 low. Check the PA current to Q7 often. If desired, you may lift Q7 from the circuit board and set it down vertically, with a heat sink attached to the metal body for improved heat dissipation. The TIP31 transistor Q7 is quite rugged; because of this virtue, I chose it as the PA amplifier. 73

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Monoband Yagi

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Radio Shack. I mounted the antenna at the top of the pole, with the sections uniformly telescoped to yield a total height of 30 feet. I obtained additional strength by telescoping the sections to this shorter length. A short mast cut from 1-1/4" aluminum tubing and mounted above the rotor brought the total antenna height to 33 feet. If you use a pole, as I did, don't attempt to extend the pole to its maximum height. Very little will be gained in radiation angle, but the structure will be weakened considerably.

I attached the pole to my eaves at a height of 10 feet using the mounting bracket. I then guyed the pole near the top using Kevlar™ line sheathed in Dacron™ (available from Radio Works). This produces a strong, inconspicuous guying system.

Performance Tests

In three months I have logged 107 countries with the new antenna, most of those on SSB and most with signal reports of 5-9 or 5-9 plus. "Big Signal, AB4GX" has commonly been heard. The power used varied between 50 and 1200 watts output, although the antenna should handle full legal power with no problems. The front-to-back-ratio agrees with the computer analysis, and I've used the existence of the null off the sides to advantage. When working East (Europe and Africa) or West (South Pacific or Asia), I can effectively null the strong South and Central American stations adjacent to my Florida QTH.

This is the first time in 27 years of hamming that I have used a yagi, and the first occurrences of QSOs interrupted by hams telling me that there must be "something wrong with your equipment because you are pinning my S-Meter and blocking my receiver." This sometimes while barefoot, and while I have ended QSOs in the interest of peace and harmony, I have also developed a new respect for the gain of this antenna. I have found I can work almost anyone I hear, most often on the first call, and power management coupled with operating courtesy are much more visible requirements. You cannot have a "Big Signal" without also having a "Big Responsibility." And all this on a push-up pole, and with shortened elements! Enjoy, and please let me know your experiences if you construct this "residential yagi." 73

Contact Ken Kemski AB4GX at 3745 Allenwood Street, Sarasota FL 34232.

Parts List

QTY	Item
2	½" x 12" hardwood dowel
4	1" x 6.5" hardwood dowel
1	1-¼" x 3' aluminum mast pipe
4	½" I.D. x 1' clear plastic tubing
4	½" diameter x 5' aluminum tubing
4	½" diamater x 16.5" aluminum tubing
4	⅜" diameter x 4' aluminum tubing (cut for proper length, as shown in Figure 6.)
8	⅜" diameter x 5" aluminum rod
2	1-¼" I.D. U-bolts for mast
8	plumbing clamps for ½" pipe
12	pipe clamps for ½" pipe
1	1" x 3" x 24" pine
1	1" x 3" x 22" pine
1	1" x 2" x 4' pine
1	1" x 3" x 6' pine
1	1' x 1' x ¼" plywood (cut up for the 4 cleats)
	#12 wire
	#16 enameled wire
1	1:1 balun - Radio Works #Y1-4K
	Kevlar support wire - Radio Works
12	self-tapping screws
12	eyelets
1	Fiberglas kit (optional) - K-Mart or equivalent