When you have thoughts of moving up to the big time, the primary consideration should be your antenna. Most of us don't have the room or whatever to put up what our fantasies dictate. KØSR has worked out more than a happy-medium solution to that problem in more than journeyman fashion.

A Compact, Four-Band Quad Array

BY STEVE ROOT*, KØSR

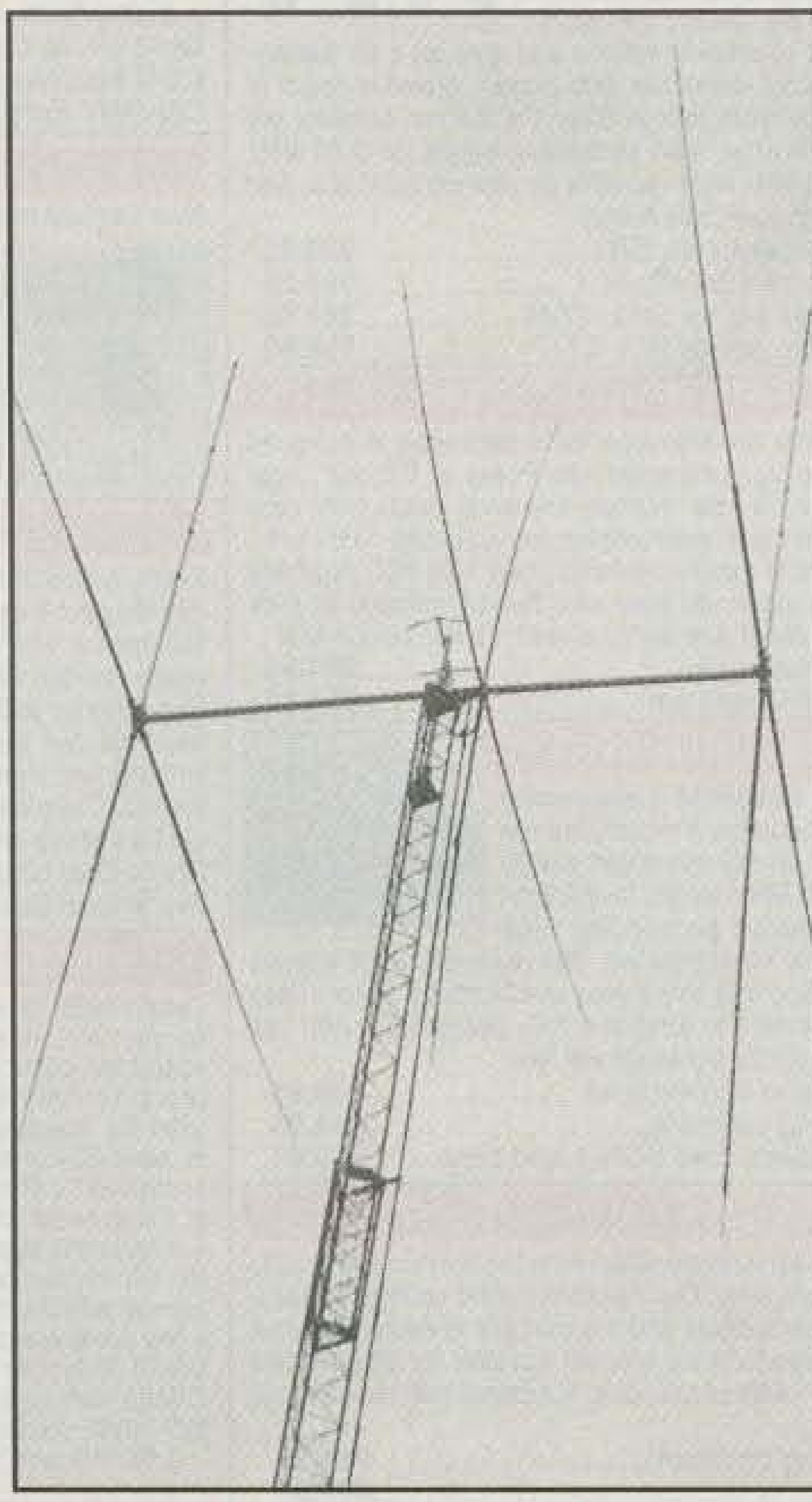
Every once in a while someone who has built a better mouse trap comes along. Steve Root, KØSR, has done just that. Over 300 countries worked and confirmed on 40 is no small achievement. It requires a really good signal to accomplish such a feat from the north central part of the U.S.A. (plus top-notch operating!). Not only is there the 40 meter antenna, but the system lent itself to the addition of a 20, 15, and 10 meter quad. Here is Steve's antenna system, and it's a good one.
Lew McCoy, W1ICP

One of my favorite bands is 40 meters, and while wire antennas are sometimes suitable, they really are not my cup of tea. I wanted a beam, and after much thinking and searching, I decided that a quad was the answer.

My goal was to design an antenna that had gain and directivity on 40 without severely compromising the higher bands. Also, most important, the antenna had to fit my space. After much study, the answer became apparent—a 2-element quad on 40 meters. However, a full-size 40 meter quad was just not practical. But a quad, even if it was electrically short, would provide at least 5 dB of gain, plus good front-to-back ratio.

From my studies on quads, I found that with careful attention paid to symmetry, a good, clean pattern would result. Not to be ignored was the fact that if I had the 2-element 40, I also had room for at least 3 more bands—3 elements each on 20, 15, and 10. These additional antennas could push 9 to 10 dB gain each, all fitting on the same boom.

The antenna had to be compatible with my existing tower and rotor, and have a total wind area of less than 15 square feet. Also in my design criteria was the antenna could be assembled by one or two people, making the project even more feasible. If an army equipped with a boom truck was required, then it was simply not practical for the average installation. The final consideration was cost. If the project exceeded the cost of a 40 meter Yagi, a tribander, and the associated rotor, then again the project would not be practical.



The KØSR quad. The driven element (center) is near the tower and approximately 8 feet from the director end. Note the double-truss wires at the center of the boom, one on each side of the mast. This double truss gives much more strength to the system. (Photos courtesy Ramona Root)

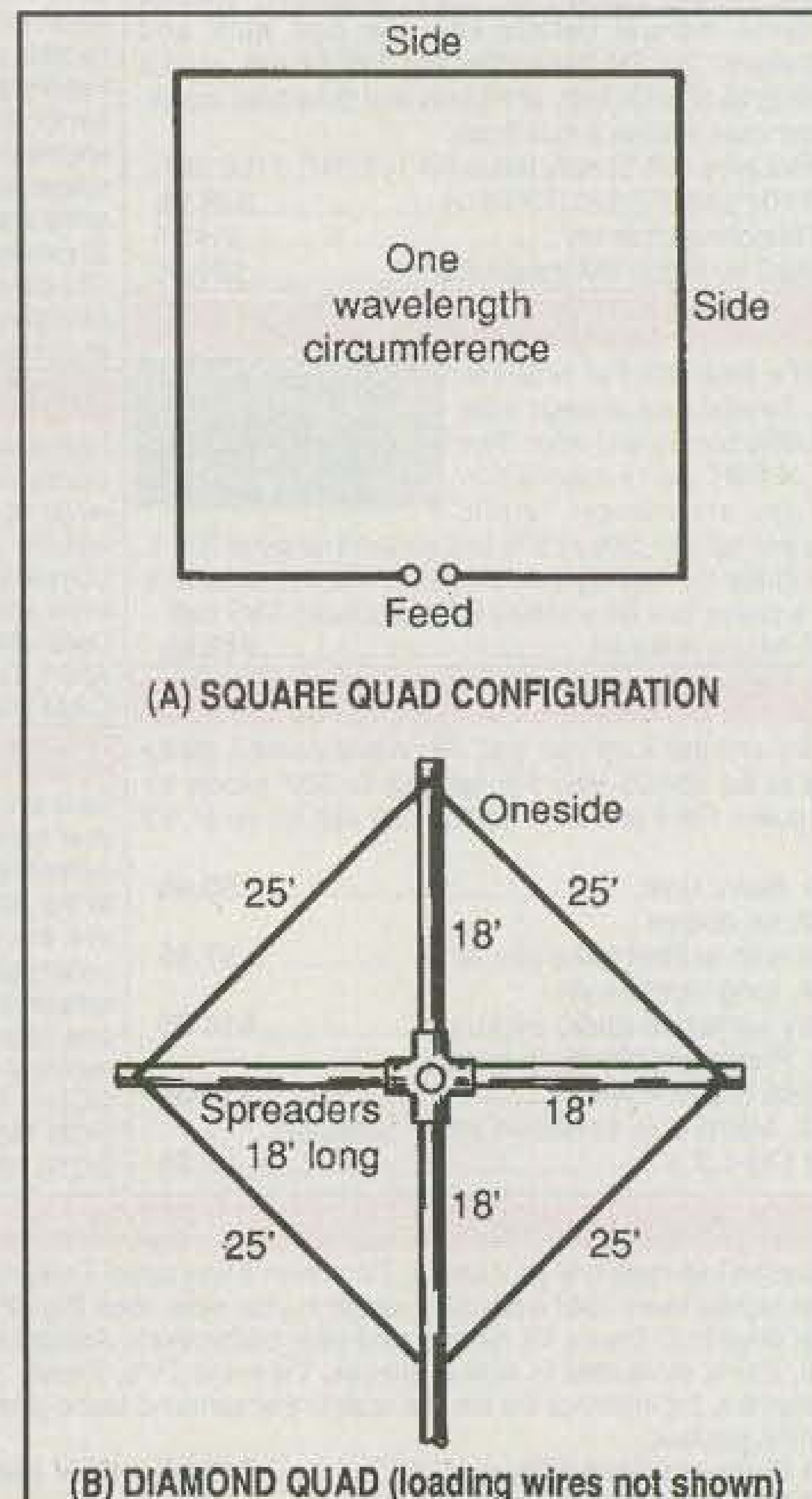


Fig. 1– There are two quad configurations that can be used—the square at (A) and the diamond shape at (B). In my case I used the diamond configuration. As you can see, for the 40 meter quad my sides are 25 feet and the vaulting pole spreaders are 18 feet from the boom to the outside. The actual wire dimensions are given in Table I. At (B) I have only shown the wires for the 40 meter loop. The other bands would fit inside this loop.

Configuration

Because of the proximity of my tower to the house, a boom length of 18 feet was chosen. This allowed me to use the roof as a platform from which to work. I also favor shorter booms for mechanical reasons; wind loading isn't as severe, so it is easier on the rotor. The 18 foot boom length also works out well for the 3-element arrays on the other bands. Therefore, my first consideration was boom length. Because element spacing for 40 meters isn't critical with two elements, spacing with a 40 meter driven element

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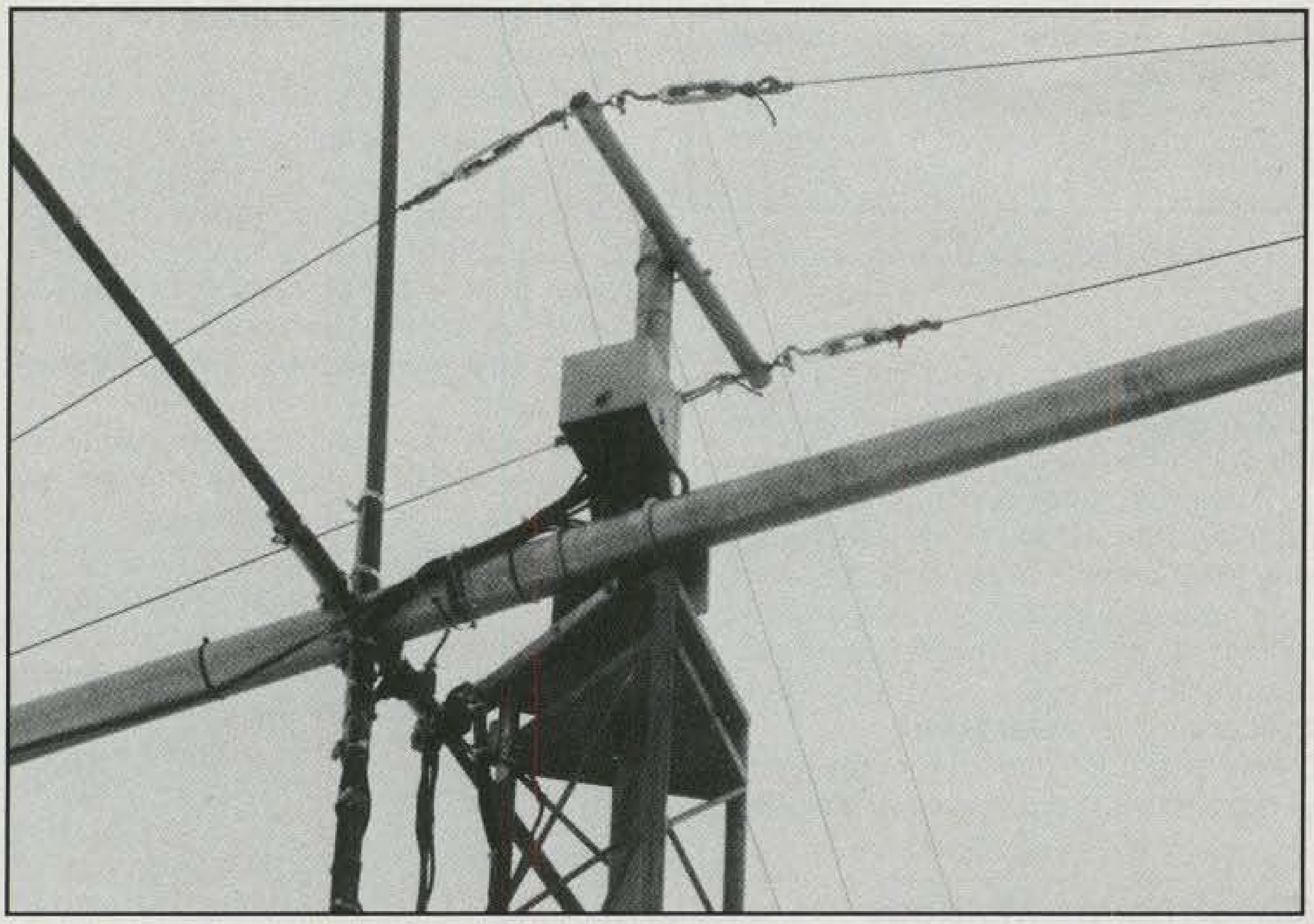
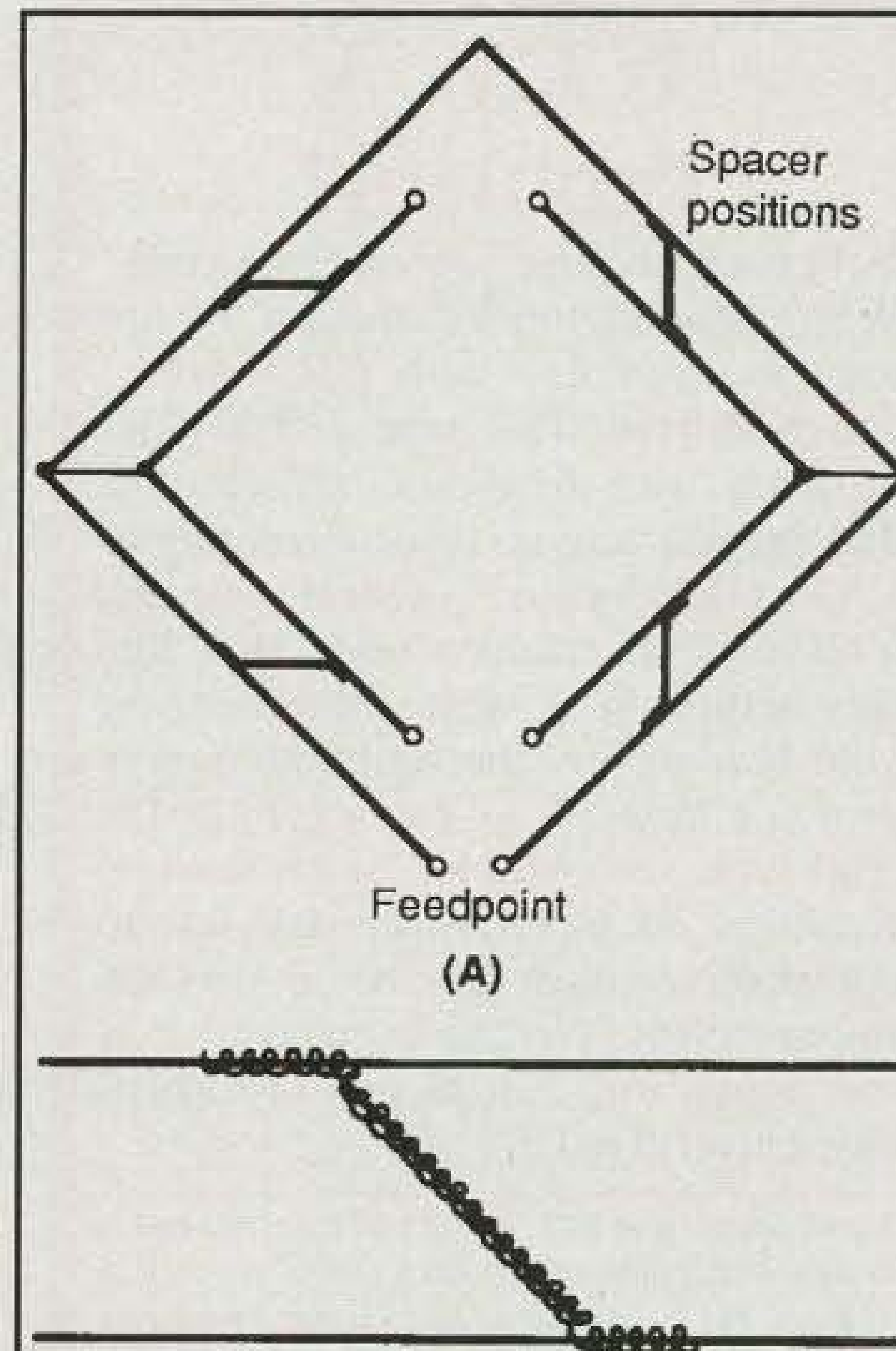


Close-up of the double-truss arrangement. The remote antenna switch (in the box) is also visible.



Detail of spacers using spiral wrap material otherwise the wires could become twisted in a strong wind. This could be any suitable insulator, as if you were making ladder line.

(B)

Fig. 2– At (A) is the system for loading/shortening quad elements. The method originated with G3FPQ and has proven to be very successful. The loading wire is 12 inches from the quad element. Side dimensions are 25 feet. Tuning wires are about 16 feet long for the driven element, and 19 feet long for the reflector. Spacing between element and tuning wire is 12 inches. Spreaders are each 18 feet long. At (B) is the method for holding the loading wire in place. The material is spiral wrap, which is used for bundling wires. A piece of wooden dowel is used in the center of the spiral to hold the piece steady. I have used this system for a couple of years through wind, snow, etc., and it has proven to be trouble free.

and reflector could be anywhere from 16 to 24 feet.

As I said, a full-size 40 meter quad would have been rather large, so the 40 meter elements are not full size. The spreaders required for a full-size element 40 meter quad would have been 26 feet long, plus each side at 30 feet plus, and that was simply too big. Techniques for shortening an element have proven successful in other applications, with a lower practical limit being about 70 percent of full size.

For the reader who doesn't understand quads, let me give a little explanation. A regular-size quad uses elements that are approximately one full wavelength in circumference. Also, a quad has four equal-length sides. In addition, a quad can be put up in a "square" configuration or a "diamond" shape (the sides are always equal in length in either configuration; see fig. 1).

In my case, reducing the size of the 40 meter quad meant that each of the four sides would be 25 feet in length. Thus, 25 feet on a side, with 18 foot spreaders, is what I used. The shortened element is tuned to resonance by adding capacitance at the side corners of the element using additional lengths of wire (fig. 2).

This method has the advantages of being easier to adjust than linear loading, and the loading isn't in the high-current part of the loop. The high-current points are where most of the radiation from the element occurs.

Element lengths for the higher bands were developed empirically, based on what I've used in the past. Resonance in my case is biased toward the CW end of the band. Other published dimensions would probably work as well (see *The ARRL Antenna Handbook* and Bill Orr, W6SAI's *All About Cubical Quad Antennas* book).

A quad loop is a lower Q device than a dipole, so its length isn't as critical. The parasitic elements are tuned closer to the driven element for the same reason, typically being only 3 or 4 percent different in length.

As mentioned above, there are two possible configurations for the quad—the "square" and the "diamond." The square doesn't hang down the tower as far as a diamond shape, but from a mechanical standpoint the diamond is superior. It lets freezing rain water run off the wires instead of accumulating. With the 40 meter elements it also allows for longer tuning wires. Also, the current points of the loop are farther apart, increasing gain (gain from stacking).

Most of the wind load is in the big elements at the ends of the boom. A mast to boom truss removes the bending movement from the boom and makes the whole array much more rigid. A double truss was used to provide lateral support—one truss on each side of the mast, because a single truss would have the center upright spreader in the way.

Choice of Materials

The boom is a piece of 3 inch diameter aluminum irrigation pipe. This material is readily available, and going to the larger diameter makes for a stronger design.

The spreaders were fabricated from vaulting poles and commercial 13 foot fiberglass spreaders. Fiberglass holds up well to weather and is quite strong. Vaulting poles are readily available and are extremely strong (for source, see the notes at the end of this article). It might be possible to extend standard spreaders with aluminum tubing, but the introduction of other conductors in the near field of the antenna would be undesirable.

The wire in a quad is obviously the actual antenna, but remember that it also is an important structural member as well. When the wind blows, the wire sees considerable flexing and straining. Because of this, stranded No. 14 copperweld was used for the element wires on all quads. I also have had success with a single strand of No. 18 copperweld, which is

Band	Reflector	Driven	Director
40	100	100	
20	73	71	68.375
15	49.083	47.5	26.251
10	36.542	35.19	34.417

Table I– KØSR's element lengths.

very inexpensive and light. Do not use soft drawn copper wire because it will stretch forever.

The spreader to boom clamps are commercial units. I don't know if there is any way to fabricate a clamp that is as strong, light, and straightforward as a one-piece aluminum casting. These clamps have been used for years on various quads I built and have never failed.

The boom to mast plate is a piece of scrap aluminum and some muffler clamps.

Construction Methods

Three different-size spreaders are used. The middle element in the array uses standard 13 foot commercial spreaders. The end elements use 18 foot spreaders made from standard 13 foot spreaders and vaulting poles. The upright spreaders in the diamond configuration hold up most of the weight of the wire, so they have to be stronger than the others.

This antenna uses 15 foot long vaulting poles with a 3 foot extension, cut from a standard spreader. The side and downward spreaders are standard 13 foot spreaders extended with a 6 foot piece of vaulting pole. It broke my heart to take a saw to those beautiful 15 foot vaulting poles, but it is less expensive to use standard spreaders to make up the length, and you really don't need the full diameter out at the end with the light-duty spreaders. This minimizes wind load.

To join the standard spreader to the vaulting pole, a shim was made from a section of black rubber hose found in the local hardware store. Although close to the proper wall thickness, etc., it required some sanding to achieve a snug fit to the inside diameter of the vaulting pole. A 6 inch long slit was cut lengthwise in the end of the vaulting pole, and a stainless-steel hose clamp was used to make a compression fit. No slippage has been observed.

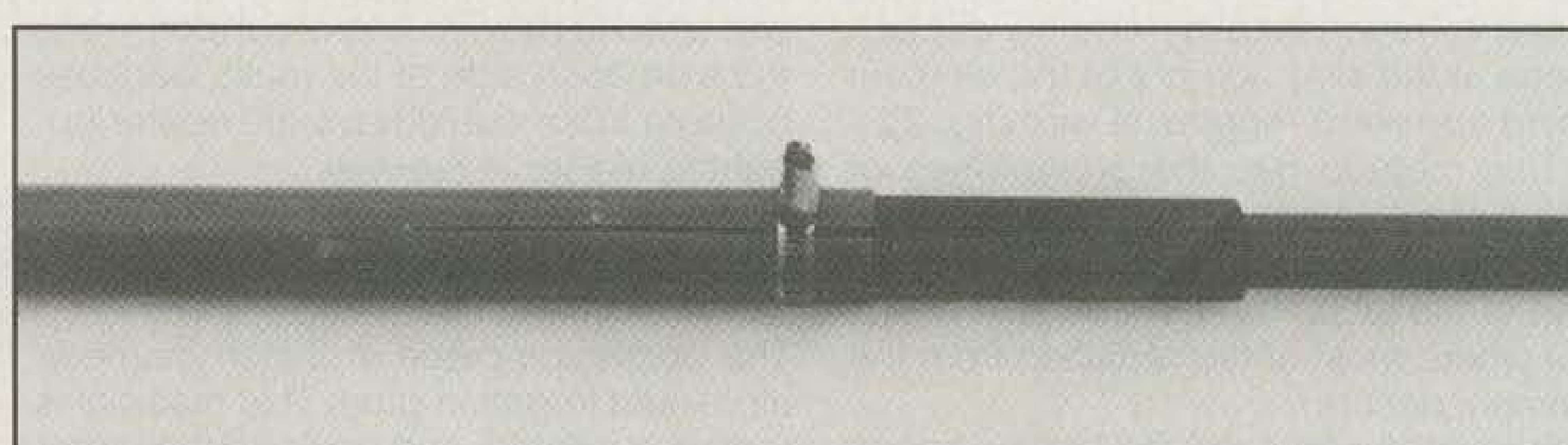
The wires were cut to length using a 100 foot tape. A one inch allowance was made on both ends for splicing. If the splice in the wire lands on top of a spreader, considerable flexing may occur at the solder joint. For this reason, the splice should be offset. Then it will see only a pulling stress when the spreaders move in the wind.

To attach the wire to the spreader, I prefer the method first described by Landskov.[1] The wire is first tied to the spreader using string in a criss-cross fashion. This is followed by fiberglass filament tape and then regular electrical tape. The filament tape will deteriorate due to ultraviolet radiation, but the electrical tape will shield it. A cable tie over the tape will keep it from unraveling into little banners flapping in the breeze. This method allows for some adjustment of tension, and also eliminates the need to drill holes through the spreader. The traditional method, using holes, will weaken the spreader and may result in breakage. Remember that my antenna has been up for a few years in severe Minnesota winters, so I know the techniques prove out.

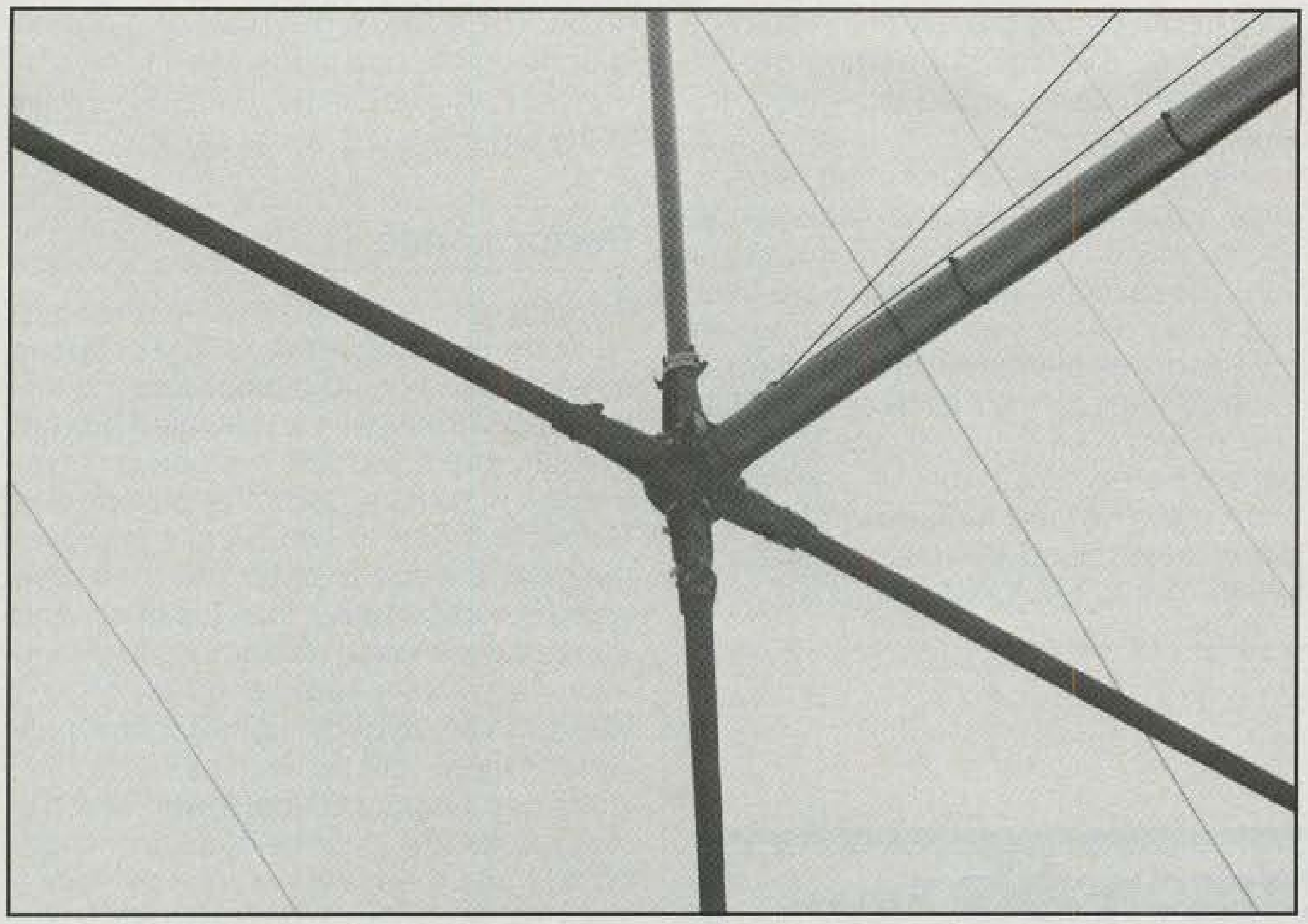
To maintain proper current distribution in the element, it is a good idea to keep the assembly as square as possible. To do this, the wire is marked off with pieces of tape at each "corner" position. The attachment points out on each spreader were marked with a pen. The two points should intersect; if they don't, something isn't square. The dimensions I used can be found in the Table I. Start with the smallest loop (10 meters) and work outward. When the 40 meter elements are built, the tuning wires should be made as long as possible, since they will be trimmed later to tune the element to the proper resonant frequency.

It isn't necessary to string the element like a violin! Even though this may appear pleasing, the extra tension will promote wire breakage. Just enough tension should be used to hold the element in shape. The spreaders should flex. Think about the abuse a fiberglass fishing rod can handle!

The feed point of each driven element deserves special consideration. Small



Here is a detail of the 40 meter spreader. The large diameter is the vaulting pole, then the rubber shim, and the smallest diameter is the end section.



Detail of the spreader clamps at the boom.

loops are formed at each end of the wire, and a piece of string is run through these loops and around the spreader to make the attachment. The filament tape and electrical tape are applied over the string to complete the mechanical attachment. Next the coax is soldered in place, and the whole thing is weatherproofed with a product such as Coax-seal®. It is very important to keep moisture out of the end of the coax. With the diamond configuration, the downward spreader provides a solid position for the feed point, and the feed line can be dressed along the spreader and back to the boom. This will minimize movement at the solder connections.

The spreaders are held to the boom clamps with stainless-steel hose clamps. It isn't necessary to "crunch down" on the spreader, just hold it firmly in place. Otherwise a broken spreader can result.

Each element is assembled on the ground, and brought up to the boom one at a time. I have a crank-up tower, and when it is nested, I can reach the end of the boom from the roof of my house. Alternatively, a tall step ladder could be used. With a free-standing tower, the boom could be placed at an appropriate height for assembly and then the completed antenna hoisted up to the top.

Tuning and Feeding

Proper current distribution is necessary for a good antenna pattern. This is achieved with element geometry and with a good balun at the feed point. The current-type balun works well and is compact. It consists of a number of ferrite beads placed over the outside of the feed line, near the feed point. The amount of inductive reactance is proportional to the number of beads and frequency. I used "Super Beads," available from Radiokit, Amidon, and The Wireman. Radiokit also sells a balun kit that uses 5 beads and is rated down to 160 meters. I used 5 beads on 40 meters, 4 beads on 20 meters, and 3 beads on 15 and 10 meters. The beads were taped up and sealed against moisture; otherwise they could crack in the winter.

There are two alternatives to the beads. One is to use a linear sleeve balun. This device is made from a quarter-wave length of braid placed over the feed line and electrically attached to the feed-line braid at the end away from the feed point. It is inexpensive and simple to construct.

Another simple method of keeping the feed coax shield "cold" for RF is to grid dip the shield with the antenna attached. If a dip shows up in the band, simply add a few feet of coax to get the dip out of the band, and the shield will be cold, preventing feed-line radiation.

A separate feed line for each band is run to a remote antenna switch placed on the mast. Even though tying all the feed points together has been a standard practice, I know that common feed will cause interaction problems, both on 40 and 15 and 20 and 10, complicating impedance matching. There are commercial units available, or one could be constructed using relays.

The loaded 40 meter elements are tuned to resonance by introducing capacitance at the side corners (see fig. 2). This method was developed by G3FPQ, and described by Devoldere in his book.[2] The technique has been applied differently here due to the diamond shape of the element. Longer wires are possible this way.

The spacers seen in the drawing keep the tuning wires from twisting around the element during windy conditions. Any light-insulating material would work. I used pieces of "spiral wrap" material (used to bundle up wires) with a stick slid down the middle. The ends simply were wrapped around the wires.

The four-band reflector was built first and placed on the tower. The lower corner of the 40 meter element was made like a feed point. This permitted a small loop to be placed in the loop so that the resonant frequency of the element could be measured. This was done using two different instruments, a grid-dip meter, and a noise bridge.

The length of all four tuning wires is trimmed to keep them the same length and to maintain proper current distribution. The reflector was tuned to 6.8 MHz, or 3.5 percent below the design frequency. The driven element was then tuned for the best impedance match at 7.05 MHz. This may not be the best way to tune a parasitic array, but it worked! The impedance match of the higher bands is primarily determined by reflector spacing, which in this case is fairly close to 50 ohms. The addition of a matching device is undesirable due to the need to weatherproof it, and adjustments are difficult up in the air. It really is unnecessary.

Performance

It is difficult to estimate how well an antenna works in absolute terms. The previous antenna used on 40 meters was a quarter-wave vertical with an elevated ground system, and it was left in place for comparison purposes. On both stateside and DX signals one to two S-units improvement with the quad was typical. In no case was the vertical better than the quad, and due to the low noise characteristic of loop antennas, it was surprising how often it was possible to copy signals that simply weren't there with the vertical.

My quad is on a 50 foot tower, which is really quite low in terms of a wavelength on 40 meters, yet the antenna exhibits a reasonable pattern. It has been observed that in DX pile-ups this array will outperform vertical or wire arrays, and hold its own with Yagis at 70 to 100 feet.

An antenna that doesn't stay up isn't worth much, so most of the design centered on mechanical considerations. This quad has been up since August 1990 and has survived Minnesota winters and nasty thunderstorms without a problem. How good is this shortened quad on 40? I have over 300 countries confirmed on 40, no small feat for this area of the U.S.

If you have any questions or would like more information, you can write to me at the address at the beginning of this article (please include an SASE).

Appendix

Suggested additional reading: *All About Cubical Quads*, by Bill Orr, W6SAI, 2nd edition, p. 46; *ARRL Antenna Anthology*, 1st edition, p. 56; *ARRL Antenna Handbook*, 15th edition, p. 12-2.

For vaulting poles contact Peterson Co., P.O. Box 25536, Salt Lake City, UT 84125 (801-972-3328).

For quad components contact the following:

Cubex Company, P.O. Box 732, Altadena, CA 91001.

Antenna Mart, P.O. Box 699, Logansville, GA 30249 (404-466-4353).

Lightning Bolt Antennas, RD #2, RT 19, Dept. Q, Volante, PA 16156 (415-530-7396).

Footnotes

1. H. Landskov, "Evolution of a Quad Array," *QST*, March 1977, p. 32.
2. Devoldere, J., *Antennas and Techniques for Low Band DXing*, ARRL, Newington, CT.