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The Quad-Quad-Quad

Sixteen three-element quads for two or sixteen nine-element quads for 432 provide a very impressive antenna and signal.

What in devil is a quad-quad-quad? For that matter, what is a quad?

There are two common uses for the word "quad" as applied to antennas. When we put up four antennas in a square formation, we say that we have a quad of antennas. We may have, for example, a quad of 10 element yagis, for a total of 40 elements. The other use of the word applies to quad elements. A quad element is a square of wire, or tubing, which usually has a perimeter of 1 wavelength.

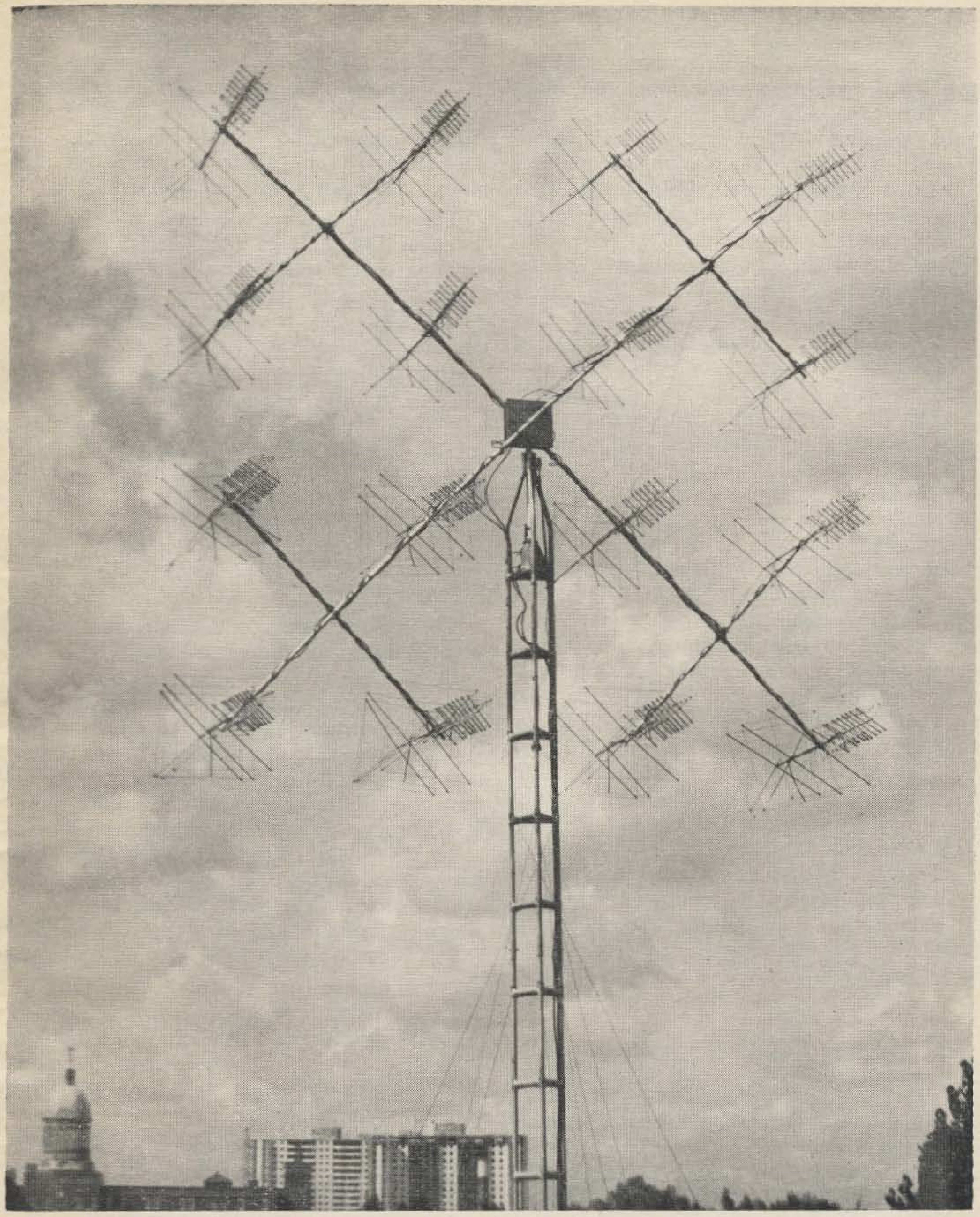
If you make four yagis with quad elements and mount them in a square formation, you have a quad of quads, or a quad-quad. Doug DeMaw described such an antenna in the May 1964 issue of 73. If you put up four quad-quads in a box formation, you have a quad of quad-quads, or a quad-quad-quad. Such a monster is the subject of this article.

In the summer of 1964, I had the booms drilled and the elements cut for four 8-element yagis. Just before buying the tubing to mount the yagis, I overheard Russ, K2KGN, extolling the virtues of his quad-quad, on 2 M. A bit of calculation revealed that it would cost less to start again from scratch and build a quad-quad, than to finish the yagis. The fact that no one else had a quad-quad in Metropolitan Toronto settled the matter. You can't do better than your buddies if you do what they are doing.

In making the quad-quad, my first mistake was the use of aluminum clothesline wire. It sure is nasty stuff to solder. My second mistake was the use of open wire feeders. Open wire is nice if you can keep the wires parallel and you live where there is no rain or snow.

In spite of its deficiencies, the antenna performed fairly well, when the feeders were not shorted.

The advantages of the antenna are low cost and small size for the gain achieved. The elements have gain over straight dipoles, because they are really two half waves spaced a quarter wave apart. This allows you to use shorter booms for a given gain. With three elements, the boom is so short that you can support the boom behind the reflector. This keeps the supporting structure out of the antenna's field, which is always good. It also allows you to mount half of the array below the top of the tower, since the tower will be behind the reflectors. With the center of the array right at the top of the tower, there is no need for a long strong mast to carry the whole weight of the array in a strong wind. Only 2 inches of my mast is between the tower and the bottom of the mounting plates at the center of the array.



The quad-quad-quad array at VE3DNR. This antenna has sixteen three-element quads on two meters and sixteen nine-element quads on 432 MHz.

Designing the beast

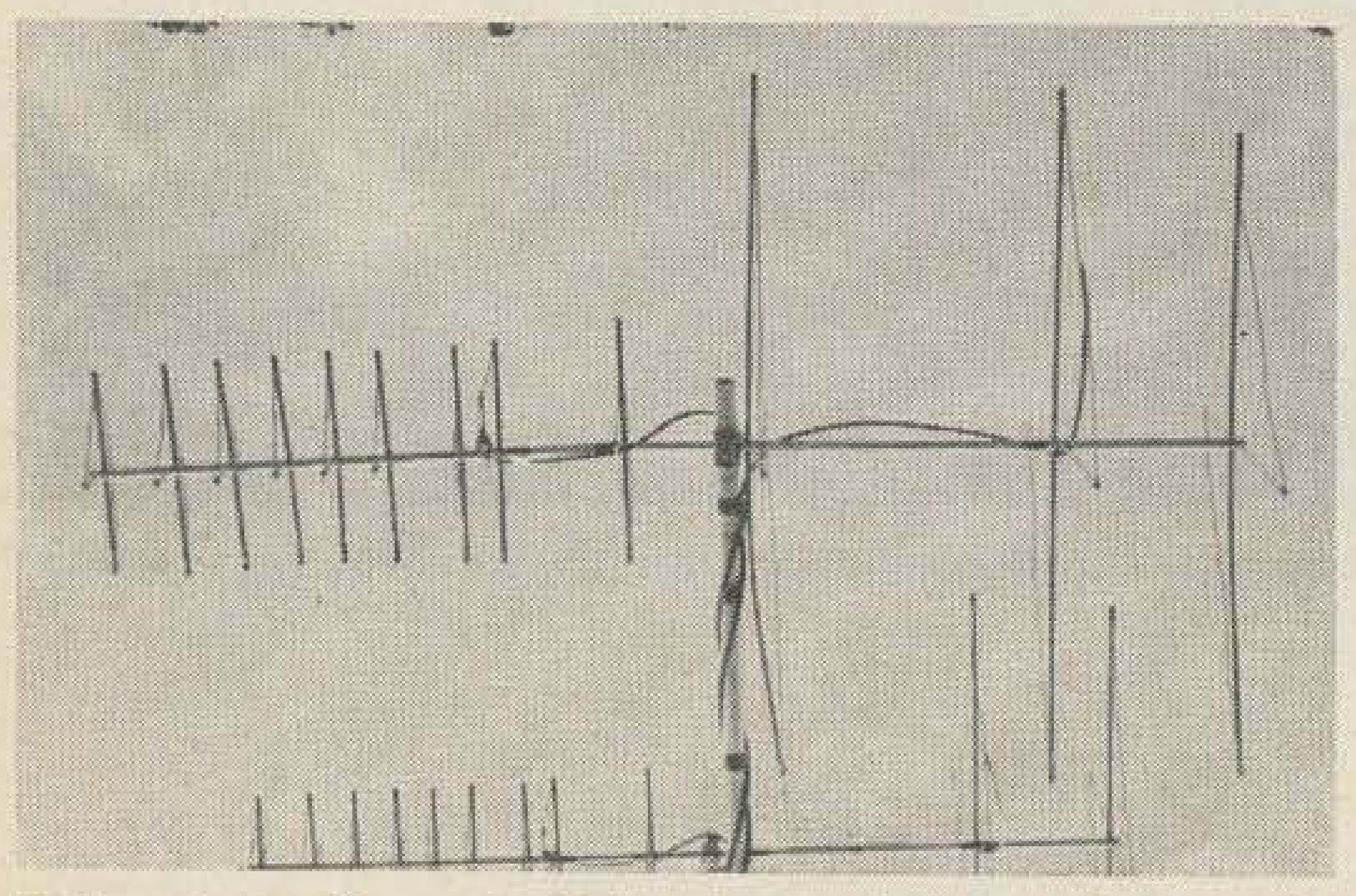
After I had the quad-quad up, Russ, K2KGN, put another bug in my brain. How about 16 quads? At first it seemed almost impossible for me. After months of thought, during the winter of 1964-1965, the difficulties disappeared one by one. Measurements and construction were done during the summers of 1965 and 1966.

When you start thinking about a quad-quad-quad, you soon realize that the spacing between yagis will be small, or the beast will be awfully big. A little more thought, with much calculation, reveals that this beast could also be awfully heavy. One of my early designs had a calculated weight of 120 pounds.

You must fight excessive weight as you would when building an aircraft. You would be surprised at the weight of such things as coax. The final design has a calculated weight of 54.4 pounds, including the mast and mounting plates. It is so light that I can lift it by the mast and remove the rotor, which is mounted inside the tower. The mast rotates in a collar at the top of the tower, so it is not necessary to hold it from going sideways.

I wanted to avoid mounting the booms cantilever style, but I still wanted to have the supports behind the reflectors. The solution was to extend the boom on the back side of the supporting tubing, and to put some sort of counter weight on that end. A nine-element quad for 432 MHz has the same weight as a three element quad for 144 MHz. So it was decided to put a 144 quad on one end of each boom and a 432 quad on the other end. The result would be sixteen 3-element quads for 144 and sixteen 9-element quads for 432.

The result had to be as small as possible, so it was necessary to redesign the quads to reduce the size. On the 144 quads, I found that I could bring the reflectors within 14" of the driven element without changing the gain appreciably. The reflector length was tuned for the minimum received signal off the back. The director was not at all critical. As near as I could measure it, the gain of one quad was 8 to 10 dB over a dipole. The front-to-back ratio was about 14 dB and there is a null off the side, as is usual with quad elements.



Side view of an individual quad from the quad-quad-quad array. The nine-element 432 quad is on the left; the three element 2 meter quad on the right.

The design was actually done at 145 MHz, to cover 144 MHz to 145.5 MHz. Antennas usually cover more megahertz below the design frequency than above. When I refer to the 144 quads, I mean the ones designed for the 2 M band, not just 144 MHz.

With the 432 quad directors, I used the idea of a slow wave structure consisting of five equal elements with matching elements at each end. This was described by Loren, K7AAD, in the May 1965 issue of the VHFER. The 432 quads had measured gains of 14 to 15.5 dB.

Measurement

The measurements on the individual quads were performed indoors. Many will look with disdain on such an idea. The main dangers would seem to be the reflections from the surroundings and the effect of the surroundings on the impedance. It was necessary for me to put my hands very near to the quads in order to change their gain. I also observed deep nulls, which would tend to indicate that the reflections were not very serious. The room was not typical. It was a second floor, unfurnished, room with non-metalic insulation.

One advantage of the quad is that it is only a quarter wave wide. Therefore, it does not come as close to obstructions as would an antenna with ordinary dipoles. This would make indoor measurements more feasible with the quad than with the yagi with straight elements.

Measurements were made using the quad as a receiving antenna. A signal generator was connected to a dipole and a super-regenerative receiver was connected to the quad, through 100 feet of RG-58/U cable. There was about 15 feet between the two antennas.

The idea of using a super-regen was to get a sensitive indication of when there was a change in signal. With a large signal present, the super-regen is very insensitive to changes in signal levels. On the other hand, at the receiver's threshold, very small changes in signal can be detected. So the attenuator on the signal generator was varied so that the signal could barely be detected in the receiver. This gave a sensitive indication of when the quad was made better or worse.

The idea of using cheap and dirty RG-58/U for measurements also comes from Loren, K7AAD, in the May 1965 issue of the VHFER. Tuning an antenna for the best SWR does only part of the job. A dummy load gives a fine SWR, but it makes a lousy antenna. What we want is the maximum signal in a 50 ohm load attached to the antenna, in the receiving case. A lossy piece of coax gives its characteristic impedance at one end, no matter what is at the other end. So 100 feet of RG-58/U at 145 MHz will show approximately 50 ohms to our quad, no matter how lousy the receiver's input impedance is.

When we have adjusted our antenna for the maximum received energy, there is no more that we can do. SWR or no SWR, our antenna is putting out as much signal into a 50 ohm load as it can. So, I don't know what the SWR of this antenna is, and I don't care. I have done the best I can.

Characteristics Of quads

There are several features of the quad which should be noted. The square quad, with sides at the top and bottom, works better than the diamond quad, with corners at the top and bottom. The difference is not large, but it is measurable.

As shown on **Fig. 1**, a current maximum will be wherever you feed the quad. Since the quad is 1 wavelength around, the opposite side will have the other current maximum. This puts the current minima, and the voltage maxima, half-way between. With a square quad, the voltage maxima are in the centers of the vertical sides. With the diamond, the voltage maxima are at the side corners. Since it is convenient to have the spreaders supporting the corners, the diamond has supports at its voltage maxima. Unless these supports are high quality insulators, and therefore expensive, you lose quite a bit of power in the supports. The square quad has its supports away from the voltage maxima, and is therefore more efficient.

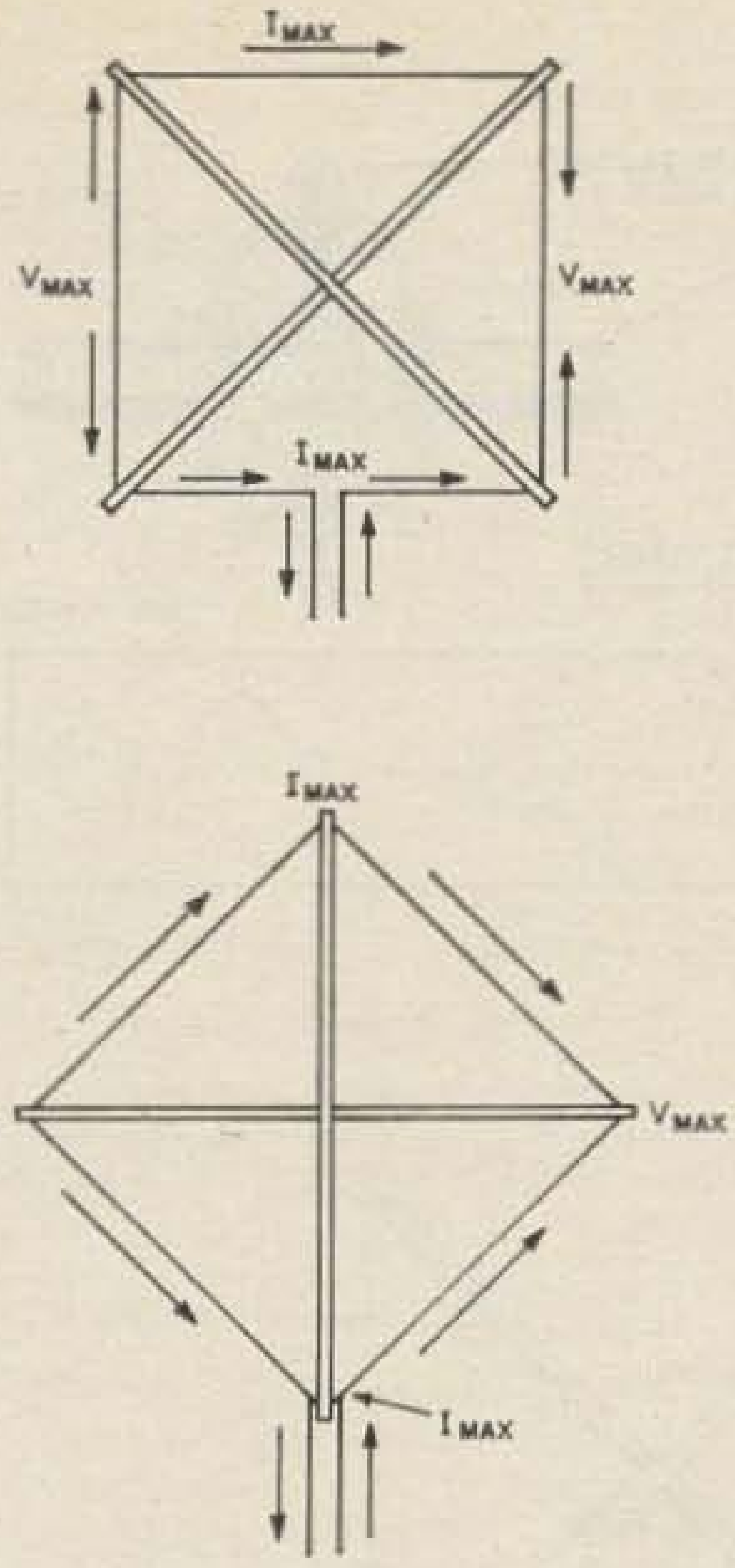


Fig. 1. The current and voltage maximums in square and diamond quads. The square quad is slightly more efficient that the diamond version because the supports are away from the voltage maximums.

For reasons which are a mystery to me, it seems better to solder the directors and reflectors at the current maxima. The opposite seems more logical to me, but my measurements clearly indicated this fact. Horizontally polarized quads should have their directors and reflectors soldered at the top or bottom.

The quad seems to be fairly sensitive to polarization. Rotating the quad on the axis of its boom by 90° produces a large change in the signal received. This is reasonable because the vertical sides of a quad, fed at the top or bottom, have currents flowing in both directions. This would cancel the vertically polarized signal.

The quad seems to be quite happy with unbalanced feeders. Measurements were made with a 432 quad fed with 50 ohm coax straight and with a 1/1 balun. The difference could not be measured. I was quite happy to save the weight of the baluns.

I can guess at the reason. With an ordinary dipole, the side connected to the braid of the coax is connected only to ground. It may get some signal from the other half, but it is operating at a disadvantage. With a quad, all of the element is connected to

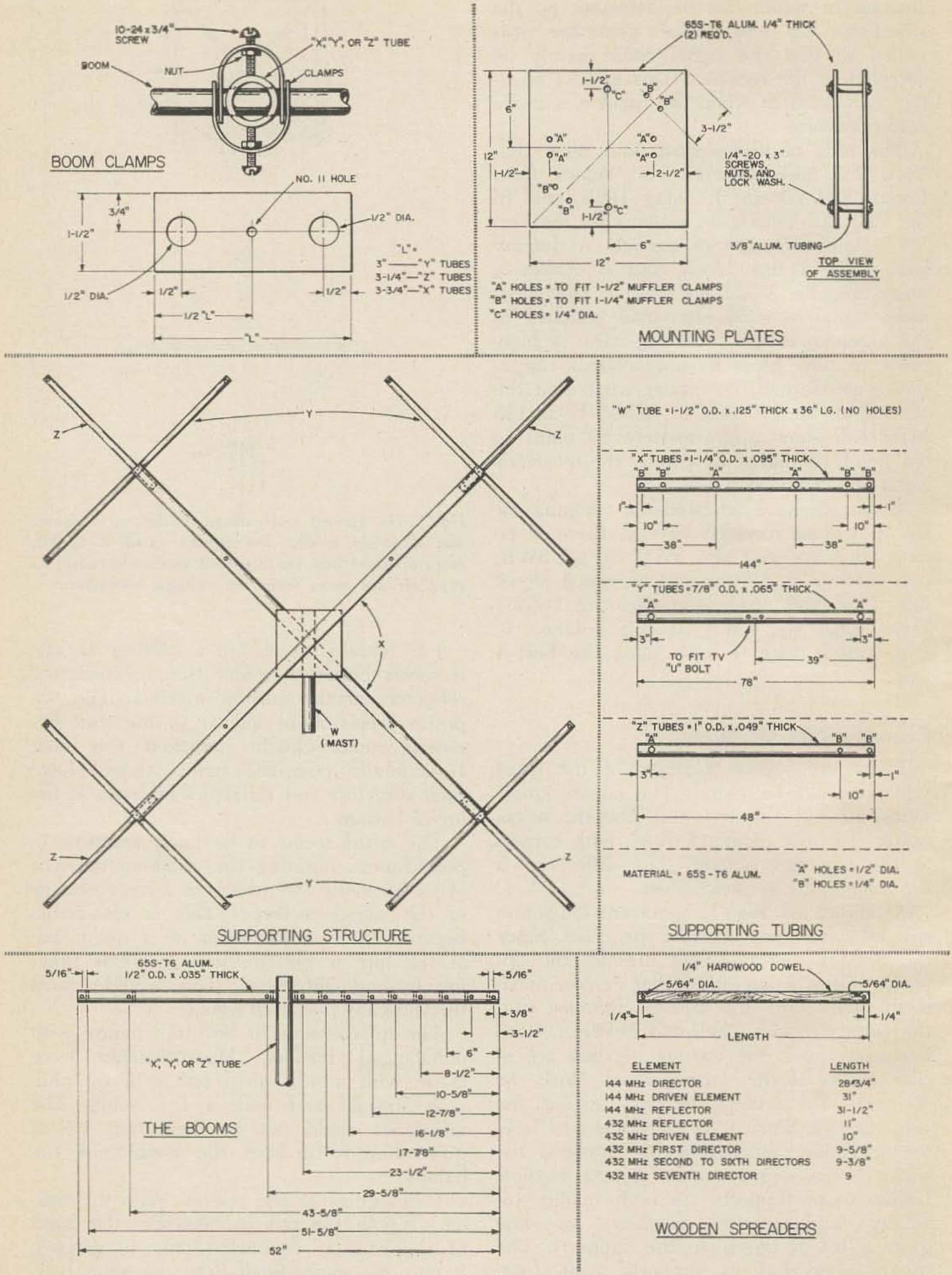


Fig. 2. Constructional details of the quad-quad-quad. The type of construction shown here results in a very strong unit that only weighs about 55 pounds.

the inner conductor, since the element is one piece of wire. It would seem that the quad element would be happier operating as an unbalanced antenna than would an ordinary dipole.

I see no reason to believe that there will be less fading with a large antenna. Although it is true that a signal will be received even if one quad is receiving nothing, it is also true that all the quads could be receiving something, but they could cancel each other. To me, one QSB situation seems as likely as the other.

If you want diversity reception, you must feed the signals from more than one antenna to more than one receiver, and add the audio signals. Only at audio frequencies can you keep the signals from the various antennas in phase. The 16 quads would seem to be good for a four channel diversity system. You could have the four quad-quads polarized horizontally, vertically and at the two 45° angles.

Construction

To save weight, the elements were made of #14 wire instead of the #10 used by Doug DeMaw. This may account for his superior front-to-back ratio. #10 wire for only the reflectors, which seem to be the most critical elements, may be a good idea. The spreaders were made of ¼" dowel instead of ⅜".

The position of the holes in the booms are specified by Fig 2. The booms were drilled with ¼" holes so that the spreaders could be passed through the booms. This saves the weight of the circular hubs that Doug used. The booms are very thin. There is danger that you will bend the booms where the holes are drilled. I bent one while installing the antenna. Since an individual quad is light, it can't do much damage if it falls. Therefore, we can take the chance that we have made the booms too thin.

It looks much better if you can make the holes in the boom line up; it looks less of a mess to the neighbors if the elements are in a line. A drill press is handy, but you can do a fair job with an ordinary electric drill. I doubt that perfect alignment will improve the electrical properties of the antenna.

The size of the elements have been given by specifying the lengths of the spreaders in Fig. 2. If the wire is under a *bit* of tension, you will come very close to getting the right perimeter every time. Even if the wire does not form a perfect square, the perimeter comes out roughly the same if the spreaders are the right lenght. The dimensions are not very critical. If you *try* to make the distance between the holes on the spreaders accurate, you should have more than enough accuracy.

Before putting the spreaders through the boom, you will find that you must file the holes in the booms. If you file the hole only enough to get the spreader in, you will need no adhesive to keep the spreader centered in the hole. It is easier on the nerves if the spreader stays put while you are trying to put the wire in place.

The booms are put through ½" holes in the supporting tubing. Therefore, you can only wire the quad on one end of the boom before putting the boom in the ½" hole. Since the 432-MHz quads have three times as many elements as the 144-MHz quads, you will naturally make the 432 quads first. You want to string as many elements as possible before getting the booms involved with the supporting tubing.

The ends of the spreaders were painted

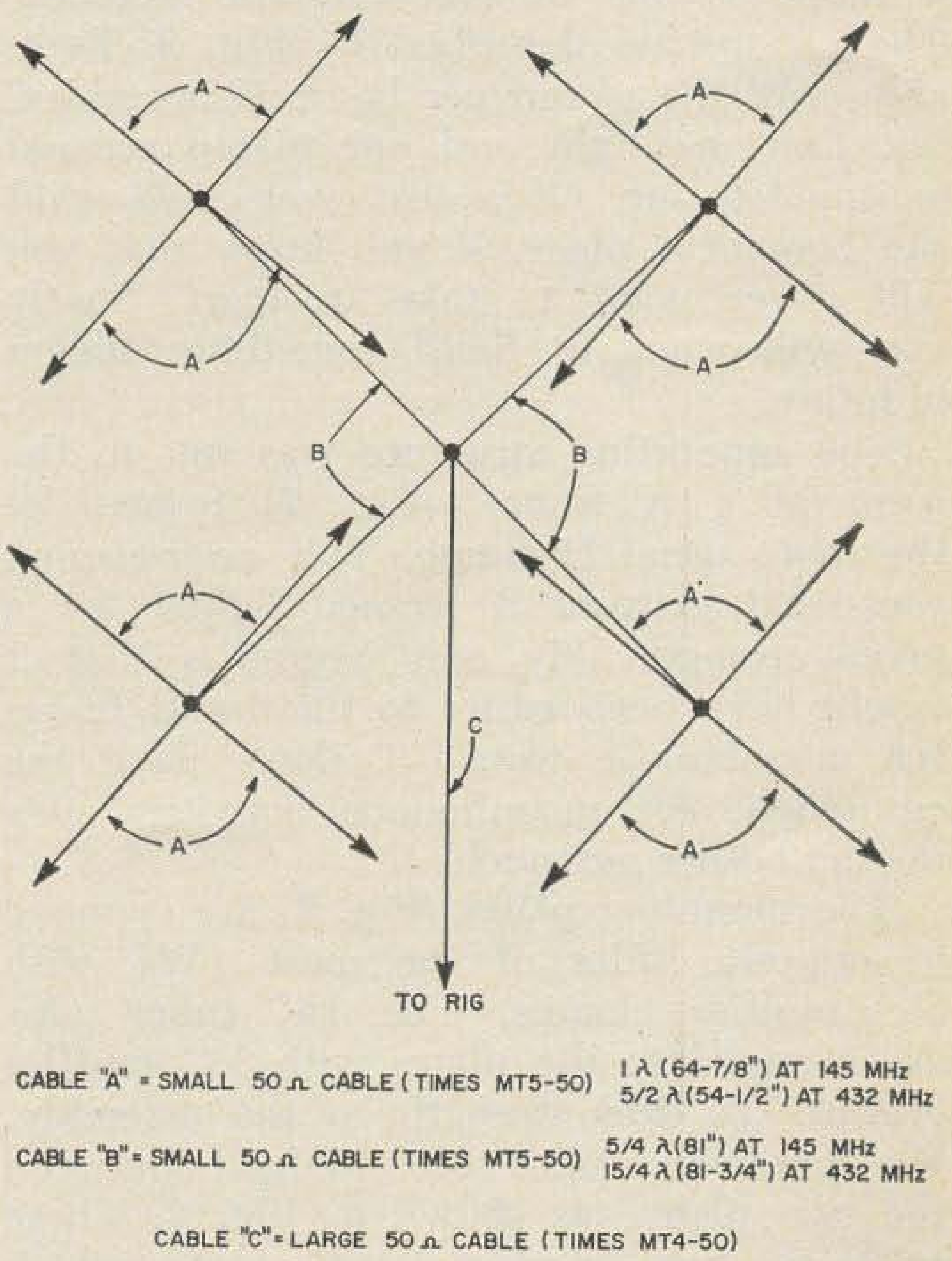


Fig. 3. Cable assembly required for feeding the quad-quad-quad; all the sections of the cable assembly are made from low-loss 50 ohm coaxial line.

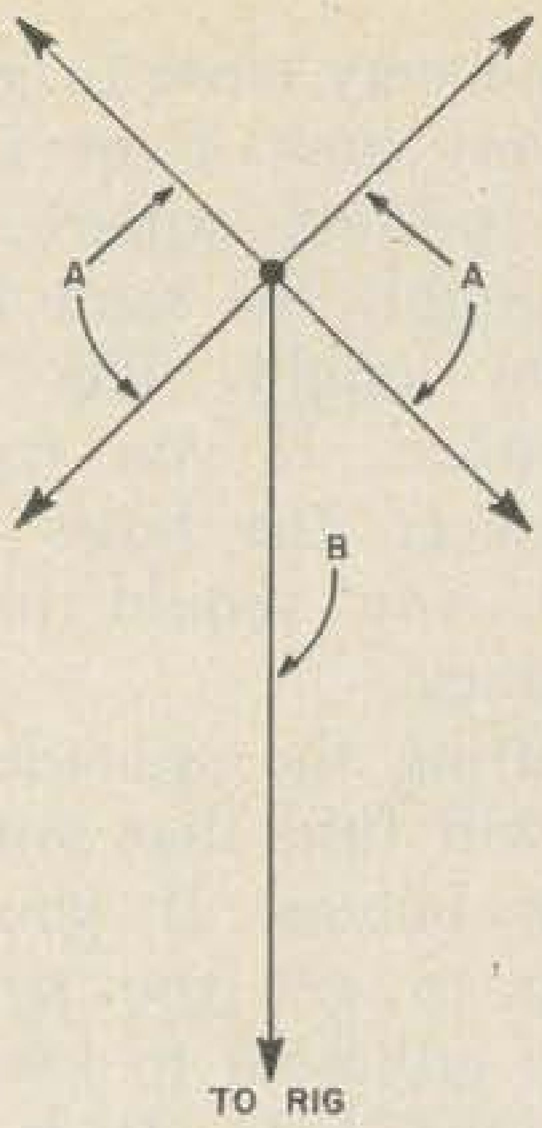


Fig. 4. Cable assembly for feeding a four quad quad-quad; this assembly uses both 100 ohm and 50 ohm coaxial line to obtain the proper impedance transformation to the main 50 ohm coaxial line.

with General Cement's Liquid Tape to cover the holes where the wire goes through. Then the whole spreader was painted with marine spar varnish.

The means of holding the booms in the ½" holes is one of the standard methods. The clamps are described by **Fig. 2**. Probably only one clamp per boom is necessary, but they are light and one clamp seemed marginal to me. Of course, you could weld the booms in place, if you know that you will never want to take it apart. Surely you will want to build something bigger in future.

The supporting structure was put in the form of a X frame. (**Fig. 2**) instead of the more usual H frame. This arrangement was used because it seemed lighter for a given strength. My only regret is that it would have been easier to tilt the H frame for moonbounce. Since I don't have the equipment for moonbounce activities, this doesn't bother me much.

The mounting plates (**Fig. 2**) are clamped to opposite sides of the mast (W) with 1½" muffler clamps. The 1¼" tubes (X) are clamped to the plates with 1¼" muffler clamps. To add strength to the assembly, ⅜" aluminum tubes are wedged between the two plates, as shown in **Fig. 2**. These tubes are held in place by ¼" screws which go through both plates and the ⅜" tubes. With this arrangement, each plate helps to keep the other plate from rotating around the mast in a wind. I can't tell you what holes to drill for the muffler clamps because your clamps will probably be different from mine.

The Z tubes fit inside the X tubes and 2" from the ends of the X tubes, using TV "U" bolts. Since you probably will use different "U" bolts from mine, I can't tell you what holes to drill in the Y tubes. The Y tubes are bolted to the same side of the X tube as its mounting plate. This makes it easier to line up the quads.

The Z tubes fit inside the Xtubes and are fastened with ¼—20 screws, 1½" long. The holes in all the supporting tubes are specified by **Fig. 2**.

Since the X tubes are separated by the plates and the mast, we must compensate for the space between them. All of the quads must line up as close as possible so that they are all the same distance from the other fellow's station. Otherwise, the signals from the 16 quads will not add in phase. This is, of course, more critical at 432 MHz than at 144 MHz.

The booms in the X and Z tubes are pushed toward the *center* of the array as much as possible. By the center of the array, I mean a line drawn parallel to the X tubes which passes through the mast. The booms in the Y tubes are pushed (in my case) ¾" away from the centers of the booms in the direction of the center of the array. The exact distance depends on the dimensions of your muffler clamps. This should make the quads line up to within ½" or so. You must also be careful that the Y tubes are clamped to the X tubes properly to make the quads line up. Finally, when clamping the X tubes to the plates you must rotate the X tubes so that the quads line up.

All of the muffler clamps and "U" bolts must be protected to prevent rust. I used Vaseline, because it is readily available and it has always done the job for me.

The cable harness

The coax connecting the quads together is small, RG-58/U size, cable. Naturally, the larger, RG-8/U size, cable would have lower losses, but more weight. Since the length of the cable from the common junction to any quad is short, the losses in small cable should be small. The additional weight of large cable seemed intolerable. Below the common junction, the weight of the cable is supported by the tower and we can therefore use large cable for the long run to the rig.

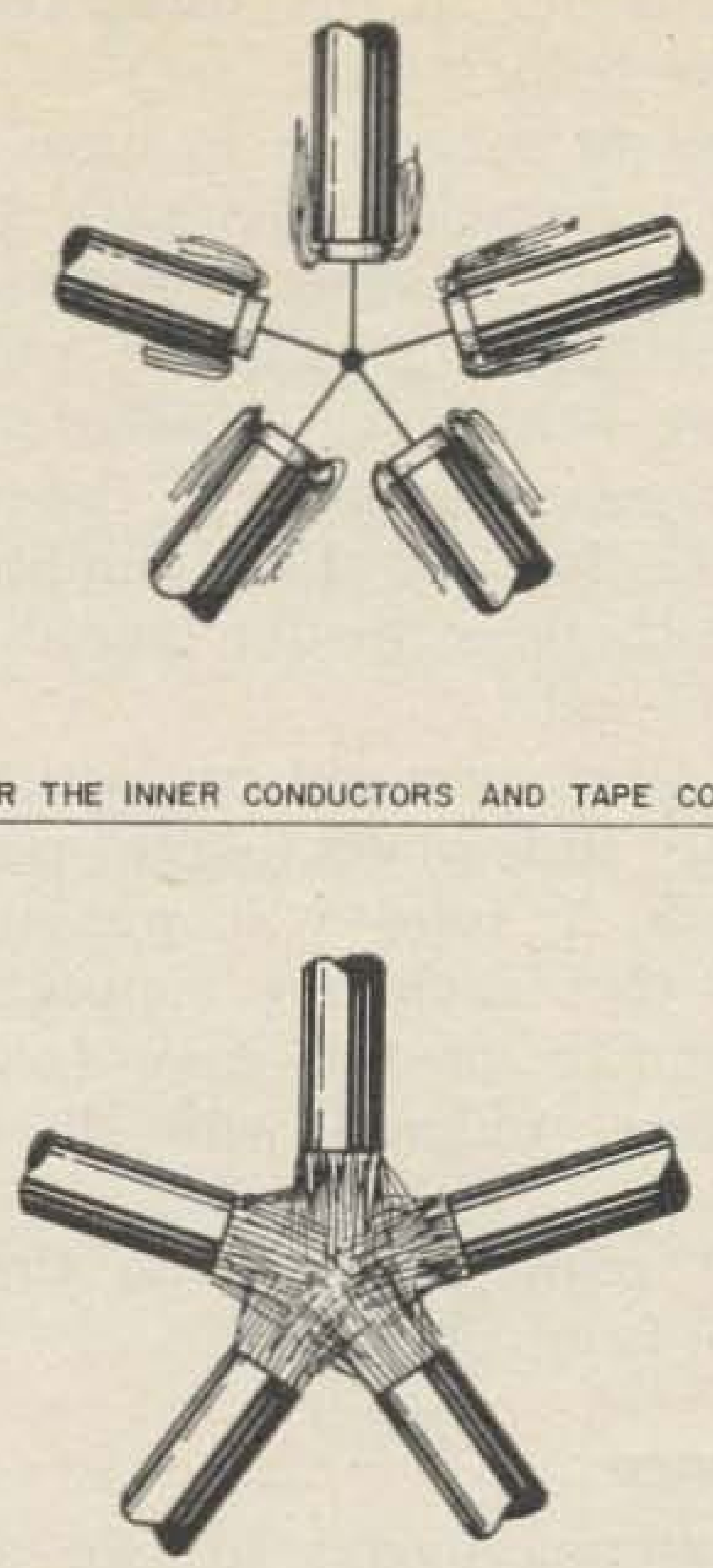
Fig. 3 shows the cable lengths for 16 quads. Each quad is designed to have an impedance of 50 ohms. So when four quads are connected together by 50 ohm cable, we have 50/4 ohms as the total impedance at these junctions. Each of these four junctions is connected to the common junction by 50 ohm cable which is an odd number of quarter waves long. These quarter wave sections transform the 50/4 ohms to 4 x 50 ohms. The main junction sees four 4 x 50 ohm impedances connected in parallel to give 50 ohms. The main cable to the rig is 50 ohms, so it is matched.

The cable used was made by Times Wire & Cable and distributed by Mosley. Any other cable could, naturally, be used if the velocity of propagation is taken into account. The dimensions in inches on **Fig. 3** are for the Times cable. The distance in wavelengths required is, naturally, the same for all types of cables.

For a four quad array, 100 ohm cable could be used, as in **Fig. 4.** An odd number of quarter waves would transform the 50 ohms of each quad (100/2) to 2 x 100 ohms. Four cables connected together would give ¼ of 2 x 100 ohms or 50 ohms, to match the cable to the rig. The most appropriate cable I can find in the catalogues for the quarter wave sections is RG-62A/U; its impedance is 93 ohms instead of 100 ohms.

You may raise your eyebrows at the idea of connecting the cables without coax connectors. If you count the number of connectors that would be needed for the 16 quads on two bands, you can see the point of avoiding connectors. The weight, let alone the cost, of all those connectors is prohibitive. Therefore, we must do our best at making reasonable coaxial connections with our trusty soldering iron.

The five cables for each connection were laid out like five spokes of a wheel, as shown by **Fig. 5.** The inner conductors were soldered and the joint was insulated with tape. The outer braids were then folded over the tape to cover each side of the joint. The braids were then soldered together to form a solid shield all around the connection. The joint is fairly strong



(A) SOLDER THE INNER CONDUCTORS AND TAPE CONNECTION

(B) FOLD THE BRAID OVER, SOLDER, AND TAPE AGAIN

Fig. 5. Connecting the coaxial cables together without using connectors. The coaxial connectors required for the quad-quad-quad are very expensive and add a lot of weight at the top of the tower.

after the braids are soldered. The finished connection is then taped and coated with some weather-proof material. I wouldn't recommend the coating that I used, so there is not much point in naming it.

Of course, you must be careful to connect all the quads in phase. All of the inner conductors must go to one side of the quads (eg. the right sides) and the braids to the other sides (eg. the left sides). If you goof on ½ of the quads, you will have a nice null where the main lobe of the pattern should be. These connections should be coated with something weather-proof.

The cables run up from the driven elements to the booms, along the booms and then along the supporting tubes. The cable is wound around the tubes and taped. The lengths of cable specified include enough slack to route the cable in the same way.

Getting it up

To show that it is possible, I decided to put up the beast alone. Unfortunately, my refusals of offers of help may have rubbed a few relatives, hams and neighbors the wrong way. It seemed important to show that anyone out in the sticks could do the job without help.

The key to success is to have a gin pole, which is a piece of pipe with a pulley on one end. You bolt the pole to whatever is already in the air, with the pulley at the top. Then you pull up whatever is next with a rope running over the pulley. My pole is 12 feet of 1¼" aluminum tubing, with a clothesline divider bolted to one end with a "U" bolt.

The antenna was put up in three sections. The mast and plates were put up first. Then each X tube was put up with all the stuff that each one supports. The two main junctions of the coax (one for each band) were soldered with the antenna in place.

It isn't really easy to do the job yourself, but it is possible.

Performance

The antenna moves in two major directions in a breeze. As you would expect, there is a strong tendency to rotate about the axis of the mast. Since the rotor is of the TV type, it is not strong enough to keep this rotation under control. There is a clamp at the top of the tower, which allows me to lock the mast to the tower. This clamp can be controlled from the ground using a "rope and pulley" system. The system works, but I hope to replace it with some electro-mechanical system that can be controlled from inside the shack. A heavy duty rotor would cost 4½ times as much and it still would not hold the antenna as well as my clamp. I have seen the way that some expensive rotors hold big ham antennas in Toronto and they impress me very unfavorably.

The other motion is rotation around the axis of the 1¼" tubing. This motion is not too severe because it is limited by how far the X tubes will twist. This motion shows that tube Y must be clamped firmly to tube X. Plenty of wind force is available to twist tube Y around the axis of the X tube. Perhaps, in my next model, I will put braces between the X tubes and the Y tubes.

The electrical performance is difficult to state definitely. This antenna is the first one at this QTH which was made at all properly. There is no well made antenna at the same height that I can use for comparison.

Comparing my results with others is also not valid. My QTH is not at all average. The 60-foot tower for the antenna sits on land 300 feet above and 1000 feet horizontally from Lake Ontario. The QTH is in Scarborough, the eastern borough of Metropolitan Toronto. To the west, my signal must fight its way across 18 miles of city and climb the Niagara escarpment, 30 miles away, before getting anywhere. To the east, there is smooth sailing over the lake for 150 miles. My coverage very much depends on the direction.

For what it is worth, I can hear W8KAY, Akron, comfortably out of the noise when his beam is on K2IEG. With the four quads, he was just audible. I have gained the ability to work the weaker boys (AM) around Rochester, N. Y. and the tower types in downtown Hamilton. On two occasions I have worked dx stations to the west and south immediately after Dennis, VE3ASO, worked them. They reported that my signal was 2 S points better than Dennis's. VE3ASO has 150 watts and 40 elements in a reasonably good suburban location in western Toronto. I have 60 watts.

I have no 432-MHz gear yet, so I can't report on the performance of the 432 quads in actual operation.

Conclusion

The quad can serve all types of two meter hams. Those who have little in funds and space can make one quad. It will fit, and rotate, in the attic or sit in the corner of the apartment balcony. Tell the landlord that it is a work of modern art, which it will be if you do a good job.

The average Joe can put up four quads without stretching the budget much; it should do as well as about 24 ordinary elements in far less space.

The ambitious can put up 16 quads, which might be enough for moonbounce. The 48 quad elements should do as well as 96 ordinary elements. OH1NL had only 24 elements in front of a screen to work W6NDG. You can also use the antenna for earth-bound contacts, because it is small enough to put on a tower. A large parabola on a high tower presents nasty mechanical problems because of the wind.

Why use straight elements, when you can get more gain with quads? Give them a try.

. . . VE3DNR