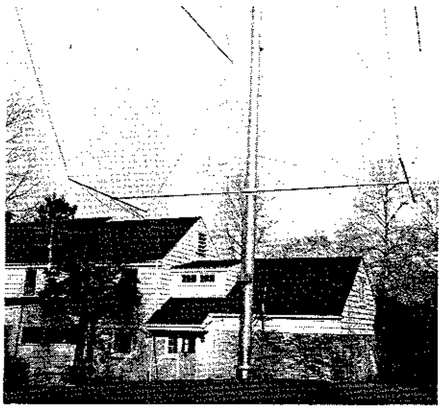
A Nearly Full-Size, Rotatable, 2-Element Quad for 80 Meters

We don't expect readers to rush right out and duplicate this antenna system — but this doesn't mean a lot of hams wouldn't like to!

Many hams have been thinking about new 80-meter antennas to improve their DX capabilities. On the higher amateur frequencies, antenna gain is relatively easy to acquire with a compact Yagi or quad. It is much harder in this respect on 40 meters. On 80 meters, however, the problem of securing any increase in antenna gain over a conventional dipole or groundplane is very difficult indeed, particularly where space is limited. Rhombics, Vs or multi-element collinear arrays become completely impractical on the normal urban or suburban lot. Even a phased vertical array is hard to handle on a city lot, and too often, performance is marginal because it is impossible to install an optimum ground system at such a location.

The author solved this problem at his QTH by constructing an almost full size 2-element quad for 80 meters. A unique tuning arrangement permits this antenna to be operated at any frequency within the 80-meter band with an SWR of close to 1. While certainly not adaptable to every individual's situation or pocketbook, a description of this antenna should be of interest to many amateurs. As far as it is known, this is the first and only set of beams, on one rotatable tower, covering all bands from 2 to 80 meters. By connecting the 2 quad elements in series to form a rotatable, bidirectional loop, the frequency coverage has been extended to 160 meters.

At this point, a few comments might be in order on the circumstances which led to this sizeable 80-meter antenna project. In June 1965, the writer returned to ham radio activity after a QRT of almost 30 years. During the first year of operation, the antennas of K3JH were a conventional commercial tribander for 10, 15 and 20 meters mounted on a 60-foot (18.3-m) tilt-over tower, and a trapped, inverted V for 40 and 80 meters. A bit of DX chasing soon led to the conclusion that better antennas were needed. Since the QTH is on a suburban lot about 175-feet (53.3-m) square, and heavily wooded, a "Christmas tree" array seemed the best alternative. Consequently, in the summer of 1966, with a great deal of help from Bob Scully, W2FXN, a 115-foot (35-m) rotary tower was installed along with full-size monoband beams for all bands from 2 through 40 meters.



The bottom support of the quad elements is shown in this view, along with the tuning-network box, which is mounted on the mast.

This rotary steel tower is 16 inches (0.41 m) OD at the base with 1-inch (25-mm) thick walls. The tower rests in a 1/2-inch thick steel bearing-tube 15 feet (4.57 m) long and 20-inches (0.51-m) OD. The bearing tube is imbedded in a block of concrete 8 × 8 × 16 feet (2.44 × 2.44 × 4.88 m) which weighs 70 tons. The tower tapers to 5-1/2 inches (140 mm) at the top, and was designed to carry nine full-size monoband beams through 125-mph winds.

Initially, the antenna complement was as follows

2/6meters	— Vert. groundplane at 115 feet (35 m)
6 "	— 6 el at 113 feet (34.5 m)
2 "	— 15 el at 109 feet (33.2 m)
20 "	— 5 el at 104 feet (31.7 m)
15 "	— 5 el at 96 feet (29.3 m)
10 "	— 6 el at 86 feet (26.2 m)
40 "	— 3 el at 77 feet (23.5 m)

A rotary ball-bearing ring and clamp at the 70-foot (2.13-m) level on the tower was used to support one end of an inverted L for 80 meters. This long wire, which could be used also on the higher frequencies, was fed through a Matchbox at the base.

Performance on 40 through 2 meters with this antenna system was generally excellent. The L and inverted V on 80, however, left much to be desired, especially when compared to the antenna performance on the other bands.

In attempts to improve this situation, several different 80-meter antennas were installed at various times between 1966 and the spring of 1969. Included in this effort were a top-loaded groundplane and a pair of phased verticals. None of these antennas provided sufficient improvement in DX performance on 80 to be considered satisfactory.

With the advent of the 5-Band DXCC, the question of how to do better on 80 meters again became a matter of concern. It was at this time that the concept of a quad of some sort, to be mounted on the rotary tower, began to emerge. Since 40-meter quads had been constructed previously, and were mechanically feasible, the thought at first was to build a half-size quad for 80 meters, using loading coils. Preliminary calculations indicated the possibility of achieving some gain over a dipole in addition to the obvious advantage of being able to rotate the array.

It was quickly determined that a half-size quad mounted at 57 feet (17.4 m) would fit underneath the 40-meter Yagi. Construction could be quite conventional using fiberglass X frames in each element, and a spacing of 0.15 wavelength.

Design Considerations

The proposed design was discussed with a number of amateurs including Jim Lindsay, WØHJ, Dunc Carter, W5IOU, and Claus Moeller, DL7CM, who were most helpful with advice and suggestions. A search of the literature disclosed that a number of loaded antennas of various types had been built. In most cases, however, performance had been judged empirically, and there was little in the way of specific comparative data on the performance of loaded versus unloaded configurations, or versus a reference dipole. Because of this, the decision was made to build and test a 14-MHz model of a half-size quad. This would enable a direct comparison between the performance of a miniaturized quad and other antennas. Of particular interest was a comparison with a dipole, since this was the more normal antenna used by amateurs on 80 meters.

Henry Pemberton, W3PN, who had become interested in the project, provided the X frames and supports from an old 20-meter quad, for use in the test model. Tom Consalvi, W3EOZ, provided some suitable coil stock for the test design. With this help, the 14-MHz model was quickly constructed. No trouble was experienced in pruning the coils and resonating the loops. Except for one bad piece of insulation on one coil, which promptly burst into flame when rf power was applied to the antenna, the driven element could be fed with a full kilowatt at an SWR of 1. The SWR, however, would rise sharply when the coils, which had no protection from the weather, became wet from rain. All testing, therefore, had to be done on dry days.

Since the 80-meter version was to be mounted on the tower one-quarter wavelength above ground, the 14-MHz model was mounted for the tests at the same relative height. Standard procedures for tuning up the quad were used, and will not be detailed here. Impedance of the loaded loop was measured at 60 ohms, so it could be driven nicely with a 50-ohm line. The bandwidth was 125 kHz, measured between frequencies each side of the resonant frequency where the SWR was 3:1. This was the result expected, due to the heavy loading.

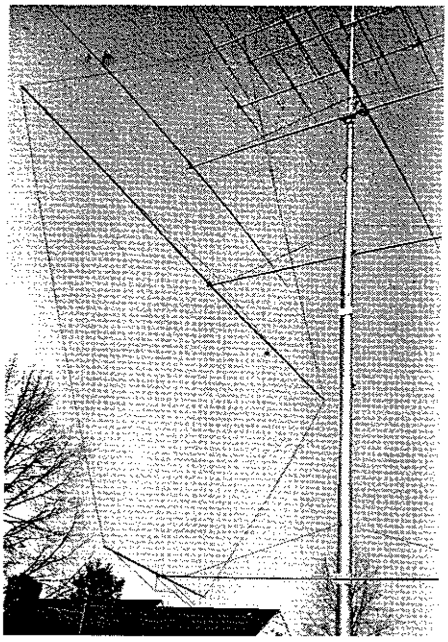
Extensive on-the-air comparisons were made between the model and various other antennas. These included a dipole at the same height above ground as the model, a -element tribander at 60 feet (18.3 m), two different inverted Vs at 50 feet (15.2 m) and a 5-element monoband Yagi at 104 feet (31.7 m). The regular antenna switching arrangements in the station were such that almost instantaneous comparisons could be made between the different antennas, minimizing QSB differences in the receiver. In the transmit mode, many amateurs compared signal differences between the test model and the other antennas. It is impossible to list the calls of all those who helped in this way.

After considerable testing, adjustment, readjustment, and minor configuration changes in the model, the results were found to be quite discouraging. The simple conclusion was that a loaded half-size quad had insufficient gain compared to a dipole to warrant proceeding any further with an 80-meter version.

Further Exploration

Before abandoning the 80-meter project, however, we decided to explore some practical ways to increase the size of the elements, preferably without using the normal-type quad X frames, which would be difficult if not impossible to handle when the antenna grew too large. This thinking developed the concept of using the 14-MHz boom at 104 feet (31.7 m) to support diamond-shaped elements at the top, and using a boom and spreaders rather than an X frame to hold the elements at the center. The bottom of the quad elements could be supported easily with a relatively light boom and spreaders near the base of the tower.

In order to reduce the size of the center boom and spreaders, the first model was kite-shaped with an included angle at the top of about 50 degrees. Unfortunately, the results were poor, and compared to a dipole there was no gain. We concluded that this configuration was so squashed together that the antenna was acting like a dipole instead of a quad. A series of configurations was then drawn up on paper. The boom and spreader sizes were varied, but the included angle at the top of each diamond element was kept at 75 degrees or more. This helped to pin down a configuration which would be mechanically feasible, and which would be a reasonable compromise among the various considerations to be taken into account. The one selected is shown in Fig. 22.



A detailed view of one of the quad elements, showing the method of supporting the loop.

Because these elements are almost full size at 4 MHz, making a 20-meter model quite large, it was decided to build and test a model of this configuration on 15 meters. The test procedures for this model were the same as those previously described for the 20-meter model of the half-size quad. This model showed substantial gain compared to the reference dipole at the same height. Also, the model mounted only 15 feet (4.6 m) above the ground compared favorably in performance with the tribander at 60 feet (18.3 m). The 5-element monobander at 96 feet (29.3 m) consistently provided better gain, as was to be expected. The impedance of the driven element was about 80 ohms. Bandwidth between SWR points of 3:1 was 250 kHz, or about twice what was measured on the half-size model.

Mechanical Considerations

After a lengthy test period, during which many on-the-air comparisons were made, the results were good enough to make the decision to build an 80-meter version of this antenna. Because of the size of the proposed antenna, considerable thought had to be given to the mechanical design to assure longevity comparable to the other beams which are rated for 125-mph winds. The wire in the quad elements is no. 12 stranded copperweld. All other metal in the antenna is aluminum or stainless steel. The two quad elements are suspended from the 20-meter boom at 104 feet (31.7 m). The insulators are five glazed porcelain knobs. Spacing is one-eighth wavelength, 36 feet (10.97 m). The 20-meter boom is 46 feet (14.02 m) long, and is made from 4-inch (102-mm) OD, 1/4-inch (6-mm) wall T-6 aluminum tubing at the center, and similar material tapering from 3-1/2 inches (89 -mm) to 3-inch (76-mm) OD at the ends. A 1/4-inch stainless steel cable supports the boom 18 feet (5.49 m) out from each side of the tower. Originally, the plan was to slide the quad elements down this cable from the tower. Unfortunately, the steel plates holding the Yagi elements to the boom on the other beams were found to be rusting because of poor plating. Rather than dismantle the beams, a crane was brought in so that these plates could be cleaned and painted by a man carried up in a boatswain's chair. At the same time, the elements were hung from the 20-meter beam, and the center boom and spreaders for the quad were installed with relative ease.

Dimensions

The 36-foot (10.97-m) center boom at the 57-foot (17.37-m) level of the tower is made of a single 24-foot (7.32-m) section of 3-1/2-inch (13-mm), 1/4-inch (6-mm) wall, T-6 tubing with 7-foot (2.13-m) sections of 3-inch (76-mm) OD pipe telescoped and bolted at each end. The boom is supported from the tower with a 3/16-inch (4.76-mm) stainless-steel cable. The spreaders at each end of this boom are 70 feet (21.34 m) long. Each consists of a 24-foot (7.32-m) piece of 2-1/2-inch (64-mm) OD, 1/8-inch (3-mm) wall, T-6 tubing at the center, with two short pieces of 2-1/8 × 1/8-inch (54 mm × 3-mm) tubing telescoped and bolted at each end to make up a length of 30 feet (9.14 m). To complete the spreaders, 20-foot (6.10-m) sections of 1-1/2- and 1-1/4-inch (38- and 32-mm) fiberglass poles are attached to each end of the aluminum centerpiece. Use of the fiberglass reduces weight and eliminates a one-quarter wavelength piece of metal from the middle of the quad element. A 1/8-inch (3-mm) cable and strut supports each spreader to minimize sag, which is very slight as may be noted in the photograph. A welded aluminum T structure and stainless steel clamps are used to hold the spreaders on to the ends of the boom. A stainless steel clamp and Teflon grommet is attached to the ends of each spreader to hold the element wires in place. The only function of the spreaders is to hold the two opposite sides of each quad element apart without too much fore and aft flopping around when the antenna is rotated. The length of the spreaders, wind loading, and safety factor dictates the heavy mechanical design.

The lower boom, which is 23 feet (7 m) off the ground, is made of a 24-foot (7.32-m) section of 2-1/4 × 1/4-inch (57- × 6-mm) T-6 tubing with shorter 2- × 1/4-inch (51- × 6-mm) pieces telescoped and bolted at each end to make the total length of 36 feet (10.97 m). To maintain symmetry, 17-foot (5.18-m) spreaders are attached to each end of the lower boom. These spreaders are made of 1-1/2-inch (38-mm) fiberglass. They are attached to the boom with aluminum angles and stainless-steel clamps. A light stainless-steel cable and strut holds the lower spreaders firm against the pull of the quad-element wires, which are attached to each end of the lower spreaders with stainless-steel clamps. The wires are taped along the fiberglass almost to the center of the spreaders, and then go off at right angles to the tuning box, which is mounted on the tower 13 feet (4 m) above ground. The distance from the end of the lower boom to the tower is about 18 feet (5.5 m), and the 36 feet (11 m) of wire which connects the quad proper to the tuning box represents loading.

Tuning

Each element, including the 36 feet (10.97 m) of connecting wire just mentioned, resonates at 4050 kHz. Thus, a small amount of additional inductive loading is required to tune the antenna to resonance within the 80-meter band. This is accomplished by putting two relatively small motor-driven coils in series with each loop of the antenna. The reversible motor for each pair of coils in each loop is controlled by a two-way toggle switch mounted on the antenna control panel in the shack. In the case of the driven element, tuning is accomplished simply by applying power to the antenna and then adjusting the loading inductances by the motor-control switch to the point where the SWR is minimum, usually very close to 1. Tuning the reflector can be accomplished by turning the back of the quad toward a distant signal, and adjusting the reflector loading coils for

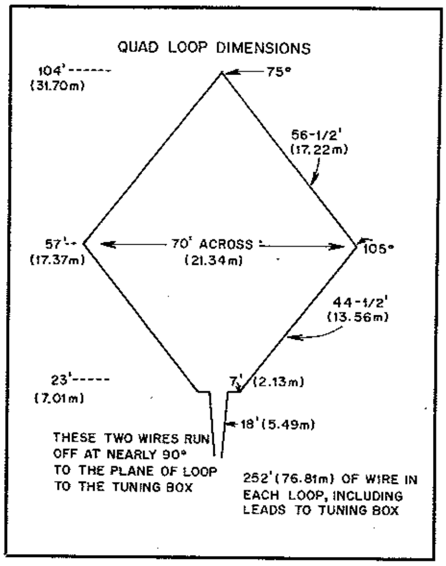
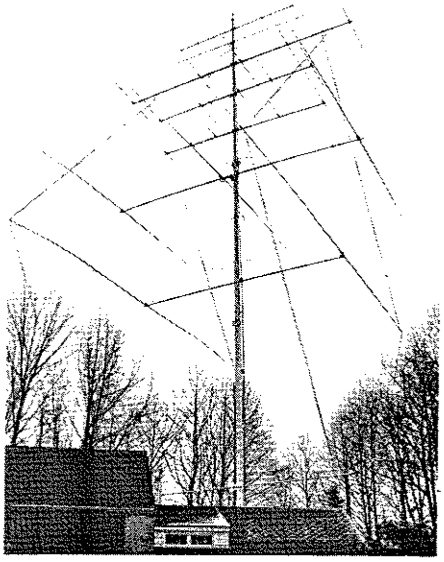


Fig. 22 — Dimensions of one of the quad loops.



Here is the complete antenna system, 2 through 160 meters, all rotatable, directional arrays.

minimum received signal. This seemed a bit cumbersome to do each time the operating frequency was changed from cw to ssb and vice-versa, so a microswitch was added to the reflector coils and motor assembly. Each revolution of the coils flicks the microswitch, which actuates a light on the control panel in the shack. By counting the blinks of the light, and referring to a chart which shows the resonant frequency of the reflector versus the number of turns of inductance in the loop, the reflector can be tuned to any desired frequency. With this tuning scheme, it is quite easy to tune the quad for best performance at any point in the 80-meter band. The bandwidth between the 3:1 SWR points is close to 200 kHz, so retuning is required only for large frequency changes within the band. Frequency flexibility otherwise is quite good.

The impedance of the driven element measures about 75 ohms. The antenna is coupled to the transmitter through a balun and 50-ohm line. The difference between the resonant frequency of the driven element and the reflector, when the latter is tuned for maximum front-to-back ratio, is in the order of only 1-1/2 percent. This probably results from the quad being only a one-quarter wavelength above the ground. The front-to-back ratio is about 20 dB, and the front-to-side, 50 dB. All measurements have an indicated gain over a dipole in the order of 6 to 7 dB. No degradation in performance, or SWR, has been observed during heavy rain. The small loading coils are protected from the weather, of course, in their aluminum tuner box, so the problem, which was encountered with unprotected load coils in the 20-meter test model, has been eliminated.

Tests were conducted with the second element tuned as a director instead of a reflector; there was no noticeable improvement in gain, whereas the front-to-back ratio was diminished. It is felt that the best results are obtained with the reflector.

Some thought was given to driving both elements at a 135-degree phase difference to obtain a cardioid pattern. It is felt, however, that the conventional quad pattern, with deep nulls on each side, and a reasonably good front-to-back ratio, is more desireable for DX. So, nothing further has been done with such a phasing arrangement.

Results

DX results on 80 meters have improved considerably since the new antenna was put on the air. On cw, the gain seems to drop off somewhat as compared to the phone end of the band. Probably this is due to the fact that the relative size of the antenna is smaller at the cw operating frequencies. Nevertheless, reports usually are from one to several S units higher than other U.S. stations with comparable power input, and conventional antennas. In most instances during pile-ups in a recent cw contest, it took only a call or two to get through, whereas, previously, the station was usually last. It was found also that contacts could be made earlier, as the band opened. In several instances like this, it was amazing to get a response from a DX station, and then to hear other U.S. stations calling without success.

Reports from overseas on ssb are outstanding. During a recent phone contest, several dozen DX contacts were made in just a few hours — everyone on the first call.

During the day, on 80 meters, it is quite easy to work into Canada or the Carolinas with good signals at both ends of the circuit. On a dipole, very often the other station is completely unreadable, if not inaudible. This points up the fact that one notices great improvement in reception with the quad compared to a dipole, which on 80 is just as important as being able to transmit a better signal.

Once it was determined that the quad worked well on 80 meters, the possibility of operating the antenna on 160 meters was explored. Since the loops independently resonated at 4050 kHz, and there was considerable inductive loading available in the coils, it was felt that it might be possible to resonate the antenna on 1.8 MHz by putting the two loops in series. Actually, with the load coils tuned to minimum, the series-connected loops resonated at 1775 kHz because of the mutual coupling. By shortening out the coils entirely, the pair of loops were resonated at 1805 kHz. Therefore, the SWR at the low end of the 160-meter band is very low.

Domestic reports on 160 meters have been excellent. Consistent directional effects have been noted by several observers when the two-turn loop is rotated. The pattern is the typical figure eight, with deep nulls off each side of the loop. It remains to evaluate how well the antenna works on 160-meter DX.

Following completion of the antenna in September, there have been several severe storms, with winds gusting as high as 65 mph. These velocities barely moved the wires and spreaders around. It is apparent that the heavy construction is adequate to handle the winds of much higher velocity · which the antenna was designed. Although it is probably one of the largest quads in existence, it certainly appears as though it will stay up a long time, even through rough weather.

In conclusion, this project could never have been completed successfully without the help of many domestic and overseas amateurs. Their reports, advice, and assistance will always be appreciated. Although this has been a sizeable and difficult antenna task, a great deal of satisfaction has been derived from carrying it through from concept to on-the-air operation. The simple lesson has been relearned with regard to antennas — that one cannot get something for nothing. Mini-size antennas are better than no antennas, but there is no substitute for full-size antennas if one wants full-size results. This material was originally presented in *QST* by Joe Hertzberg, N3EA.

The Folded Mini Quad

A full-wavelength loop can take a variety of forms. Despite the shape suggested here, the author claims good results.

An unusual type of full-wavelength wireloop antenna is in use here on 2 and 15 meters. The design, which the author had not seen previously, provides an antenna that occupies minimum space; the antenna is omnidirectional, vertically polarized, broadbanded and requires no ground-plane.

It evolves from a full-wavelength loop.[1] The loop, if fed on the side (x-y) as in Fig. 23A, radiates a vertically polarized signal. The radiation pattern is bidirectional, with maximum radiation broadside to the plane of the loop and with the highest field strength in the plane A-A′.

The loop can be deformed into a square, such as in the elements of a quad, and without much loss of efficiency into a rectangle (Fig. 23C). Vertical polarization, bidirectional signal pattern and maximum radiation from the plane A-A′ are ained.

A 90 degree bend at A-A′ and two further right angle bends at B-B′ and C-C′ transforms the flat loop into a cube. The circumference is still a full wavelength and each side of the cube measures 1/10 wavelength. Again, vertical polarization is retained, but the appreciable bidirectional radiation from the sides of the cube adjacent to A-A′ leads to a nearly omnidirectional radiation pattern.

My 2-meter antenna was constructed from aluminum clothesline wire; the length in feet was chosen by 1005/f MHz. It is fed with 50-ohm coaxial cable through a Pomona Electronics no. 1699 adapter and no matching device is used. The SWR is less than 1.2:1 from 144 to 146.5 MHz and climbs to 1.4:1 at 148 MHz. The radiation pattern was measured with a simple field-strength meter, using a half-wave dipole as pickup element and a 20-kΩ resistance in series with the 20-μA meter to improve linearity.[2] The front-to-back ratio is 1.8 dB with no prominent sidelobes apparent, but a rather sharp 3-dB dip is caused by the "shadow" of the feed line and hardware.

Performance

Fed with 10 watts and used as an indoor antenna, it gives consistent communication with 2-meter fm base and mobile stations within a 10- to 15-mile radius. It performs better on receive and transmit than a 1/4-wave whip at the same location.

A 15-meter version of the antenna was then constructed and suspended in the attic with string and tacks. It is operated with 100 watts and the rig loads almost as well as the 2-meter version, but with a slightly higher SWR. The first contacts were with California and it has since given excellent performance to the West, Midwest and South as well as to South America and Europe.

The close proximity of antenna sections radiating out of phase may lower the efficiency over that of a loop, yet, in terms of space requirement, construction cost and ease of installation (no radials!) and tuning, the antenna is hard to beat. As a full-wave loop it should have a slight edge over a vertical. The author recommends further experimentation and modification, e.g., into the even more space-saving configuration of a cylinder. This material was originally presented in *QST* by Max Blumer, WA1MKP, SK.

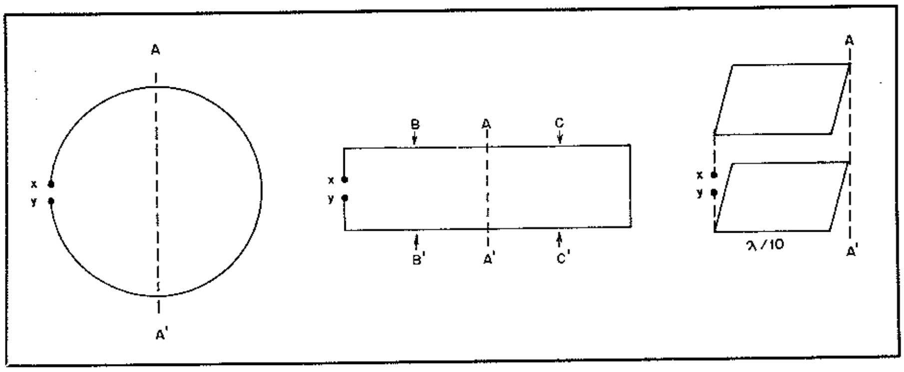


Fig. 23 — Conversion of the full-wavelength loop to the space-saving cubical configuration. The length of the wire and the vertical polarization remain but the pattern changes from bidirectional to omnidirectional. The spacing between the feed point and the adjacent side is not critical. The spacing on 2 meters is about 1-1/2 inches (38 mm), and on 15 meters is about 4 inches (102 mm).

References

[1] *The ARRL Antenna Book*, 13th ed., 1974, p. 65.
[2] *The Radio Amateur's Handbook*, 46th ed., 1969, p. 553.