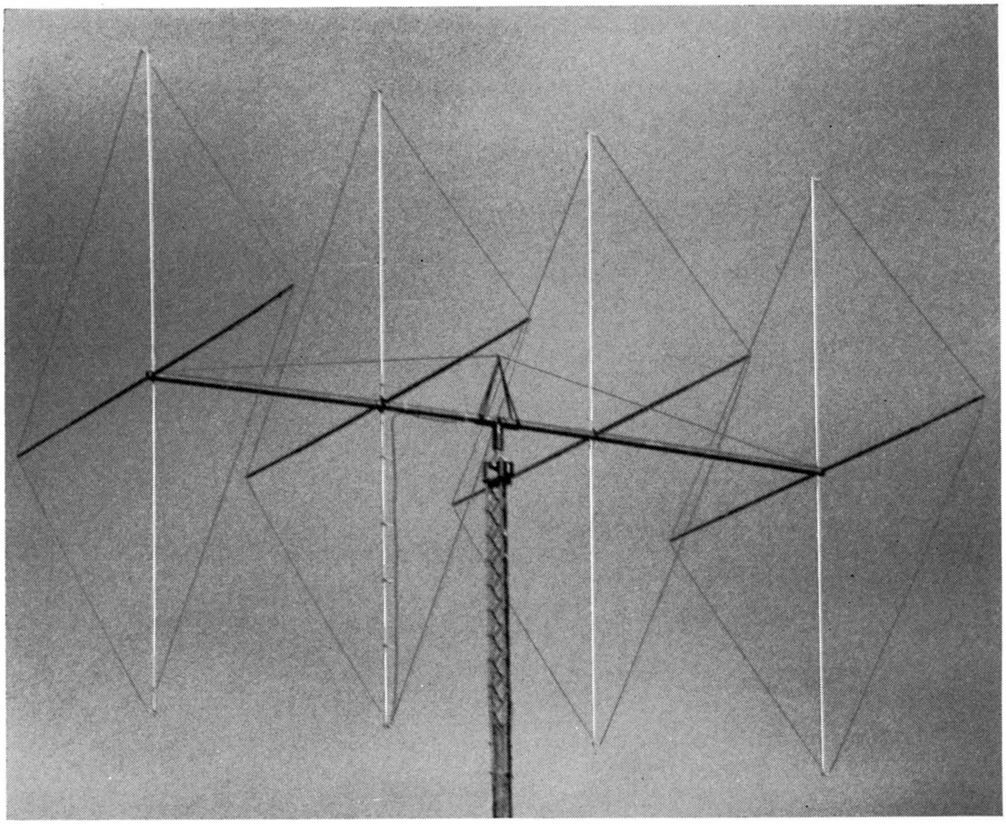


The four-element quad at WØAIW has a driven element (second from left in this view), reflector, and two directors. The boom and supports are aluminum tubing. Horizontal crossarms are broken by insulators to minimize coupling to the antenna. Continuous wire loops, with no stubs, are used for each element.

The Multielement Quad

BY LEE BERGREN,* WØAIW

The quad made its appearance on the amateur bands shortly after World War II, and since that time it has been pretty much a controversial antenna. Probably the reason for this is that some of the information published and voiced over the air has not been correct. Whether or not the quad is superior to the Yagi can usually start an argument. However, unless all the conditions are fully defined, the argument has little or no meaning. Reviewing a few of the quad fundamentals is perhaps in order before going into the details of the four-element quad shown in the photographs.

The quad in its simplest form consists of a length of wire formed into a square with a side length of approximately ¼ wavelength. The wire diameter can vary several sizes with little effect on the antenna performance. The feed-point terminals are located either at the middle of one side or at one of the corners, as shown in Fig. 1.

The author discusses the results of his considerable experience with quad antennas in this article, and in addition gives constructional details of a four-loop quad that has given an excellent account of itself in DX work.

* Radio Industries, Inc., 1319 Central Ave., Kansas City, Kansas.

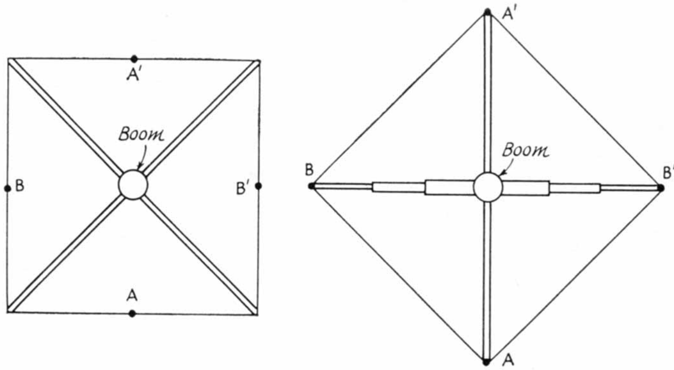


Fig. 1—Two quad loop configurations. In either case, feeding at *A* or *A'* will result in horizontal polarization; feeding at *B* or *B'* will give vertical polarization.

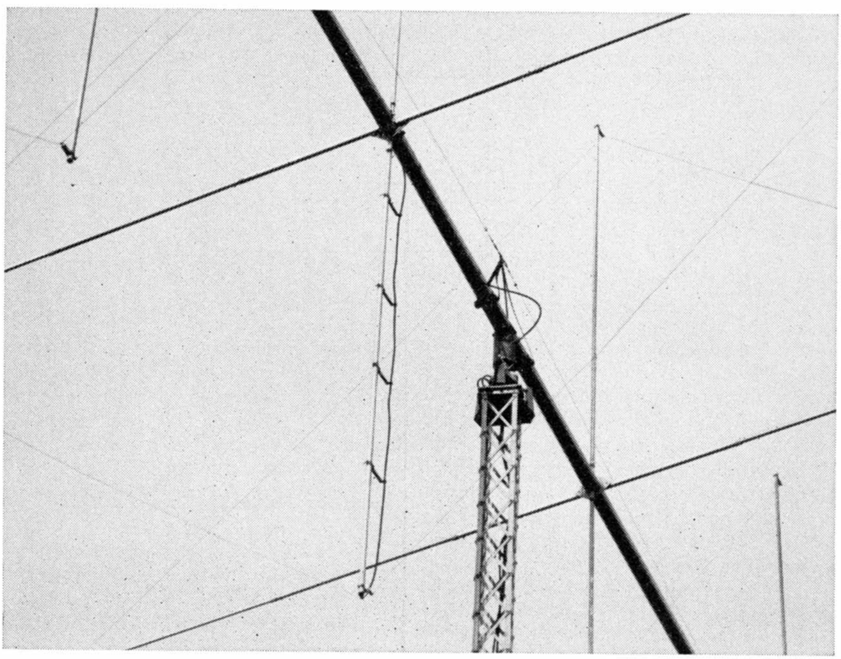
The popular quad configuration has been a driven element with a parasitic reflector. Not too much has been done with multi-element quads, and it seems to be popular belief that not too much could be gained by adding directors. Like many old wives' tales, this is far from the truth. It is well known that directors on a Yagi-type antenna will increase its directivity and gain, and it is equally true that the directivity and gain of quad-type antennas respond similarly.

Polarization

The polarization of the quad depends on where it is fed. If the feed point is at either the top or bottom, the antenna is horizontally polarized. If the feed point is at either side, the antenna is vertically polarized. Or, as illustrated in Fig. 1, feed points *A* and *A'* in either configuration will yield horizontal polarization and feed points *B* and *B'* will yield vertical polarization.

As a point of interest, the quad's response to polarization opposite to the one intended is down some 30 db. This can be proved mathematically and quite simply verified experimentally. Assume that the quad is used as a horizontally-polarized receiving antenna with an r.f. milliammeter inserted at point *A*, and that a balanced horizontal dipole transmitting antenna is located on the quad axis several wavelengths away. Power into the transmitting dipole is increased until the r.f. milliammeter in the quad reads full scale. Then if the quad is rotated 90 degrees about its center axis, the milliammeter reading will fall to near zero, showing that the response to vertical polarization is down more than 20 db. (20 db. is about the maximum that can be read from full-scale to near zero on a thermocouple-type meter.)

Why use horizontal polarization? Well, principally because this type of polarization is easier to work with. A horizontally-polarized quad with



Boom support, rotating mechanism, and feed. The coax cable is supported on standoffs from the lower half of the driven-element vertical crossarm, to reach the feed point at the lower corner of the quad loop.

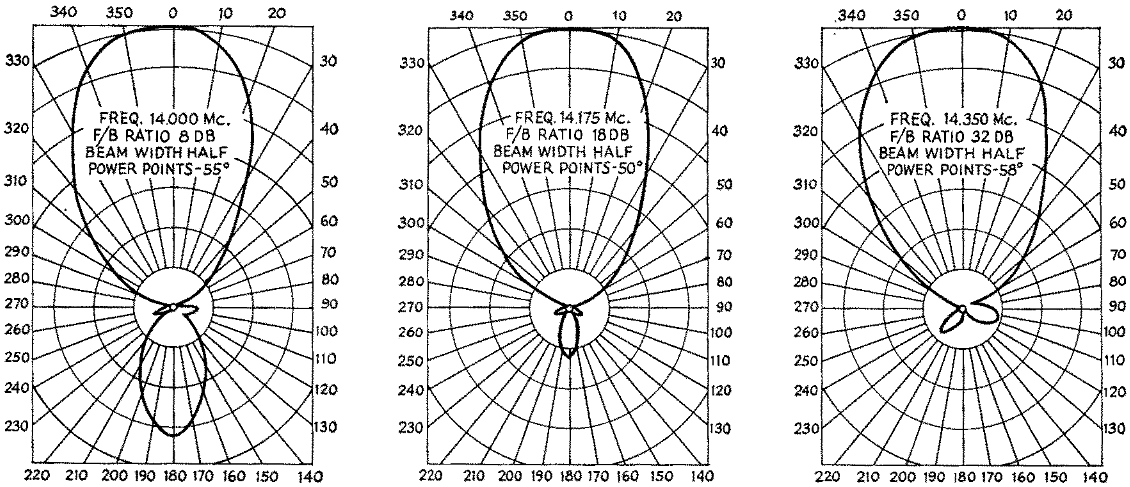


Fig. 2—Measured horizontal directional patterns of the four-element quad at three frequencies in the 14-Mc. band. Driven element resonated at the band center, directors adjusted for maximum gain at high-frequency end, reflector adjusted for maximum gain at low-frequency end.

the desired number of elements can be tuned at a convenient height above ground (¼ wavelength or so) and when put on the metal tower or pole it will still be in tune. If the antenna were vertically polarized, it would certainly be detuned when put on the tower. The reason for this, of course, is that the metal in the tower and the vertical transmission line would couple to the antenna elements, disrupting the current relationships that make it a directional antenna.

Of the two configurations in Fig. 1, the one with the feed points at the midspan has been most generally used. However, there are two good reasons why the quad should be fed at a corner. First, the vertical supports for all elements can be made of aluminum tubing. Since the antenna is horizontally polarized this metal in the vertical plane has essentially no effect on the performance and, as is well known, aluminum tubing of the hard-tempered variety is an excellent material for antenna construction. Second, the high-current points of the antenna are physically separated by a greater distance. Each element loop in a horizontally-polarized quad consists of two half waves in phase stacked vertically. The greater the physical separation of the high-current points in the two half waves, the lower the angle of maximum radiation in the vertical plane. The current distribution in a half-wave dipole is known to be approximately sinusoidal, so it seems safe to assume that the current distribution in a quad element is also sinusoidal. Using this hypothesis and by current summation, it can be shown that the stacking factor of the two half waves in phase in each element loop is improved by feeding at a corner rather than at the midpoint of a span.

Vertical-Plane Radiation

The gain and tuning of a quad antenna go hand in hand, but this is equally true of any multi-element parasitic-type antenna. The gain of amateur antennas is always referred to in the horizontal plane, because it is physically impracticable for the ham to determine experimentally what happens to the radiated wave in the vertical plane. The vertical pattern of a given antenna can be calculated, but this is the best that we can do.

But the value of a DX antenna is certainly more dependent upon what happens in the vertical radiation plane than in the horizontal plane. For a DX antenna it is foolish indeed to worry about a few db. horizontal gain and completely ignore where the radiated energy is in the vertical plane. Unfortunately, about the only control of the energy in the vertical plane is the antenna height and vertical stacking of elements. It is axiomatic that for long-haul communications the lower the vertical angle the better the results. The quad, with the two half waves stacked vertically in each element loop, will have a lower vertical angle than a comparable Yagi, both antennas being at the same height. Operationally, this means that a long-haul DX station will be heard earlier and longer on the quad than on a Yagi, both with comparable numbers of elements, boom length, and height.

Bandwidth

Another aspect of amateur parasitic beams that appears to be neglected is the gain-bandwidth characteristic. What is the gain of the antenna at the high end, middle, and low end of the operating band? Again, you can't have your cake and eat it too, and it must be decided what is wanted. Different approaches can be used to maximize the antenna gain-bandwidth, but in the final analysis the greater the bandwidth, the less the gain.

For instance, if maximum gain is desired at both 14.0 and 14.35 Mc. in any parasitic-type

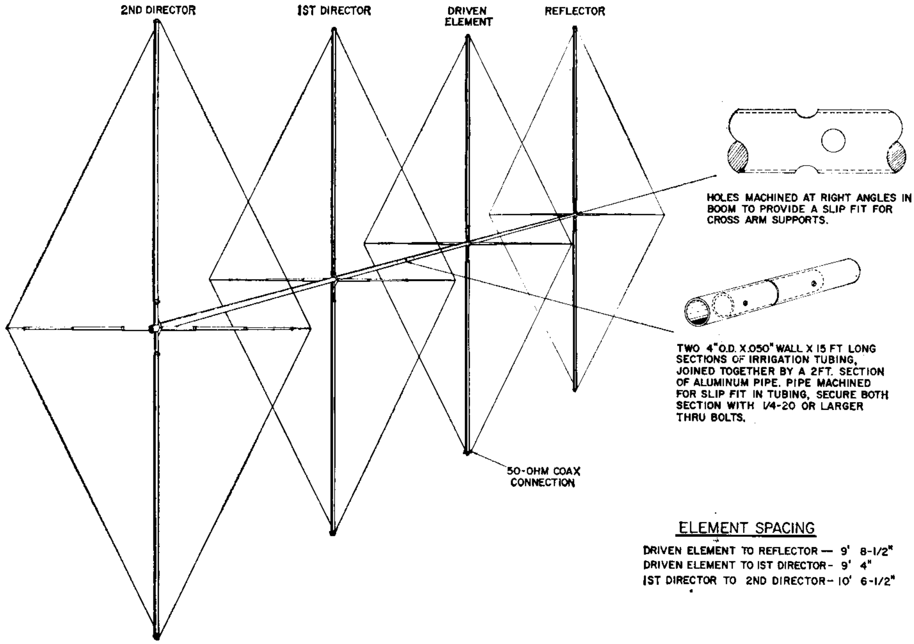


Fig. 3—The four-element quad.

antenna, the parasitic elements must be stagger-tuned. The four-element quad shown here was tuned for maximum forward gain with the driven element resonant at 14.175 Mc. The reflector was peaked at 14.0 Mc., and both directors were peaked at 14.35 Mc. Fig. 2 shows the horizontal-plane pattern at the three frequencies. Choosing other peaking frequencies for the directors and the reflector perhaps might improve the gain over the entire 14-Mc. band.

Feeding

The antenna and the feed line should always be considered as two separate and distinct problems. The antenna should be tuned as desired — for maximum gain or maximum front-to-back ratio. After tuning, the driving-point impedance should be determined and then the transmission line should be matched to this impedance.

If the impedances work out properly, a coax transmission line can be connected directly into two open terminals (as at *A* in Fig. 1). This at first would appear to have the bad effects of an unbalanced to balanced feed. However, the closed-circuit loop of the quad driven element provides a metallic return circuit for the transmission-line current and, in the writer's opinion, tends to maintain balance. The good pattern symmetry (Fig. 2) at the center frequency shown by the antenna described later gives support to this assumption.

Mechanical Considerations

The mechanical problems of a quad are more complex than the electrical problems. The wire loop elements are simple, but the supporting crossarms for the wire loops and the crossarm mounting to the boom can get complicated, cumbersome and difficult. Bamboo crossarms are structurally weak and do not stand the weather well. Fiberglas tubes for the crossarms are excellent but expensive. If consideration is given to the electrical design, aluminum tubing can be used for the crossarms.

As previously shown, if the corner feed system is used and the antenna is horizontally polarized, the vertical crossarm support can be metal tubing. However, if the horizontal crossarm support is a continuous piece of metal the antenna will not tune, since the metal is in the plane of the horizontally radiated wave and is too close to self-resonance. However, no current will be induced in the horizontal metal-tubing supports if the supports are broken into sections by inserting two insulators on either side of the boom (see Fig. 4). Low-grade insulation material that has the required mechanical strength is all that is required — hardwood boiled in wax, or phenolic plastic, will be adequate. The crossarm supports can be fastened to the boom by a spider or run through the boom as described later.

A 4-Element Antenna

The construction details for the four-element 20-meter quad are illustrated in Figs. 3 and 4. A 30-foot length of 4-inch-diameter aluminum tubing is used as the boom support. The aluminum crossarm supports for the quad wires are mounted directly through holes bored at right angles in the boom at the appropriate element-spacing locations. The crossarms are held in position by bolting to a ⅛-inch aluminum plate

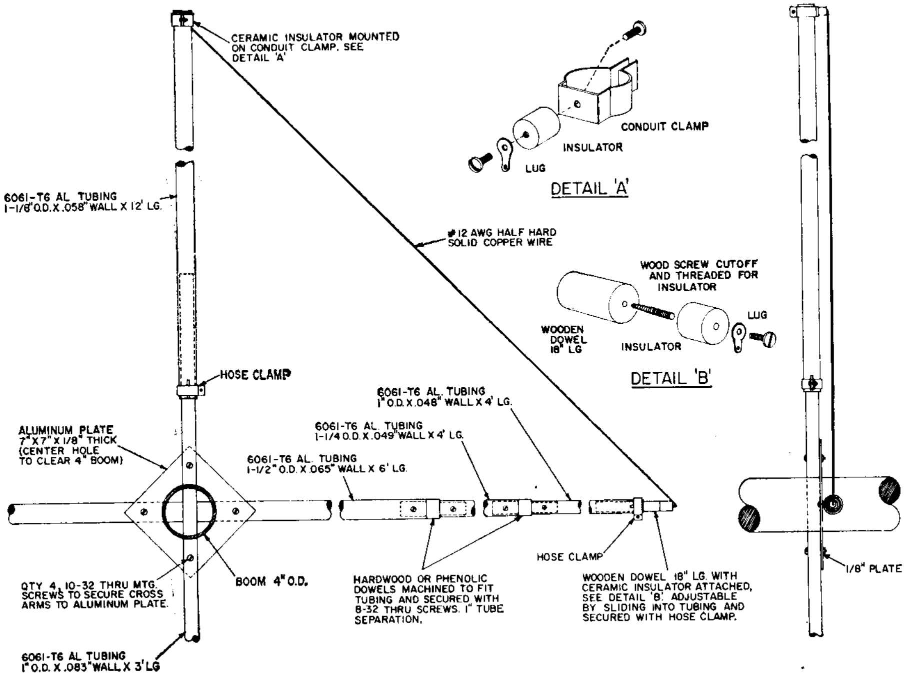


Fig. 4—Crossarm construction and mounting details.

between the two. The 30-foot boom is cut into two 15-foot pieces which slip over a 2-foot length of aluminum pipe machined to fit. This 2-foot length of pipe at the center of the boom provides material of adequate strength and thickness for bolting with clamps and adapters to the antenna rotator. The insulators in the horizontal cross-arms, if made from hardwood, should be impregnated with wax or paraffin to limit the moisture absorption.

The quad wires can be adjusted to a square configuration by adjustment of the protruding lengths of the dowels on the horizontal arms and the adjustment of the positions of the conduit clamps on the vertical arms. At each point of support the wires are mounted to a ceramic insulator 1½ inches long. Although not shown in Fig. 3, it is advisable to put a vertical support at the center of the boom to which guy wires can be run from each end. This will take the droop out of the boom.

Tuning

The tuning of a multielement quad is straightforward. This one was tuned with the boom about 17 feet above the flat roof of a four-story building. It was adjusted for maximum forward gain as a receiving antenna using an r.f. milliammeter, connected directly to the two wires at the bottom corner of the driven element, as the indicator. The transmitting antenna was a balanced dipole at the same height as the quad and 1½ wavelengths away. Twenty-five watts into the dipole gave a good reading on a 100-ma. r.f. meter.

The total loop lengths were adjusted for maximum r.f. indication at the frequencies selected to give a good gain-bandwidth product. Stub tuning in each of the elements is a good way to start the tuning procedure, but for best performance the finally-tuned antenna should have no stubs. The current distribution in each loop element is best when the element is a continuous loop with no stubs. With the tuning mentioned earlier and the element spacing shown in Fig. 3, the following are the total loop lengths for each of the elements:

Driven Element	70 feet 1½ inches
Reflector	72 feet 1½ inches
First Director	69 feet 1 inch
Second Director	69 feet 4½ inches

The impedance at the terminals of the driven element is approximately 62 ohms, measured at the center of the 20-meter band, so 50-ohm coax connected directly to the terminals was considered to give an adequate match. Fig. 5 is a plot of the v.s.w.r. over the 20-meter band. Admittedly, this could be improved, but it was not considered to be worth the effort.

A few words concerning the horizontal pattern plots, Fig. 2, are in order. These measurements were made using the quad as a receiving antenna at a boom height of 75 feet. The signal was supplied by a horizontally-polarized antenna one-half

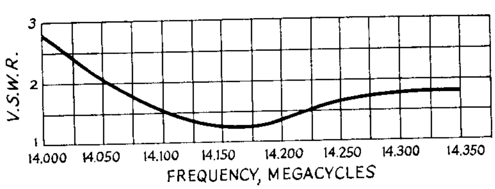


Fig. 5—Voltage standing-wave ratio in 50-ohm cable as measured across the 20-meter band.

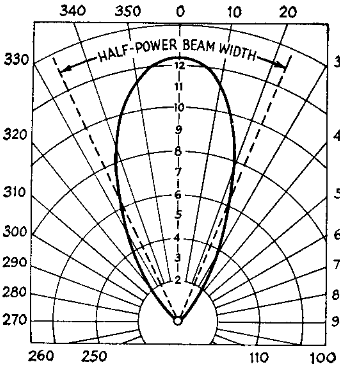


Fig. 6—Power pattern at 14,175 kc. showing the half-power beam width.

mile away. With the quad oriented head-on to the transmitting antenna, the power level at the transmitting end was set to give 3500 microvolts input to the receiver. This power level was held constant. As the quad was rotated for the pattern plot the input microvolts to the receiver were measured by comparing directly with a General Radio Type 1001A signal generator. This way the microvolts for each plotted point as the quad was rotated were accurately known.

Although, as previously stated, the horizontal gain of a horizontally-polarized antenna tells only part of the story, the pattern plots, Fig. 2, do give an indication of the merit of the four-element quad. Some conclusions can be drawn from these patterns. As indicated by the relative areas of the plots, a sharp cutoff of power gain occurs as the applied frequency is lowered from the frequency of optimum tuning, with a more gradual reduction of power gain as the frequency is raised. This then means that greater bandwidth is achieved by tuning the quad antenna for optimum operation near the low-frequency end of the desired range.

The directivity of an antenna can be calculated with fair accuracy using the half-power beam widths as taken from the plotted unidrectional power pattern.[1] Fig. 6 is the pattern plot, in power, of the four-element quad at 14.175 Mc. The calculated gain is 12.35 db. with respect to an isotropic source, or 10.2 db. over a half-wave dipole. The directivity less the ohmic losses is the gain of the antenna. If the antenna radiation resistance is not low, the ohmic loss can be neglected, and then the directivity and gain will be the same. This is a valid assumption for the quad because for a multielement parasitic antenna it does have a relatively high radiation resistance.

The author wishes to acknowledge the assistance given by WØIEV, WØPV, KØQIQ, and WØUI in making the electrical measurements on the antenna and in the preparation of this article.

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[1] Kraus, *Antennas*, Chapter 2, McGraw-Hill Book Co., New York.