Chapter 12

Quad Arrays

In the previous chapter it was assumed that the various antenna arrays were assemblies of linear half-wave (or approximately half-wave) dipole elements. However, other element forms may be used according to the same basic principles. For example, loops of various types may be combined into directive arrays. A popular type of parasitic array using loops is the quad antenna, in which loops having a perimeter of one wavelength are used in much the same way as dipole elements in the Yagi antenna.

The quad antenna was designed by Clarence Moore, W9LZX, in the late 1940s. Since its inception, there has been extensive controversy whether the quad is a better performer than a Yagi. This argument continues, but over the years several facts have become apparent. For example, J. Lindsay, W7ZQ, has made many comparisons between quads and Yagis. His data show that the quad has a gain of approximately 2 dB over a Yagi for the same array length. Another argument that has existed is that for a given array height, the quad has a lower angle of radiation than a Yagi. Even among authorities there is disagreement on this point. However, the H-plane pattern of a quad is slightly broader than that of a Yagi at the half-power points. This means that the quad covers a wider area in the vertical plane.

The full-wave loop was discussed in Chapter 5. Two such loops, one as a driven element and one as a reflector, are shown in **Fig 1**. This is the original version of the quad; in subsequent development, loops tuned as directors have been added in front of the driven element. The square loops may be mounted either with the corners lying on horizontal and vertical lines, as shown at the left, or with two sides horizontal and two vertical (right). The feed points shown for these two cases will result in horizontal polarization, which is commonly used.

The parasitic element is tuned in much the same way as the parasitic element in a Yagi antenna. That is, the parasitic loop is tuned to a lower frequency than the driven element when the parasitic is to act as a reflector, and to a higher frequency when it is to act as a director. Fig 1 shows the parasitic element with an adjustable tuning stub, a convenient method of tuning since the resonant frequency can be changed simply by changing the position of the shorting bar on the stub. In practice, it has been found that the length around the loop should be approximately 3% greater than the self-resonant length if the element is a reflector, and about 3% shorter than the self-resonant length if the parasitic element is a director. Approximate formulas for the loop lengths in feet are

$$\text{Driven element} = \frac{1005}{f\,(\text{MHz})}$$

$$\text{Reflector} = \frac{1030}{f\,(\text{MHz})}$$

$$\text{Director} = \frac{975}{f\,(\text{MHz})}$$

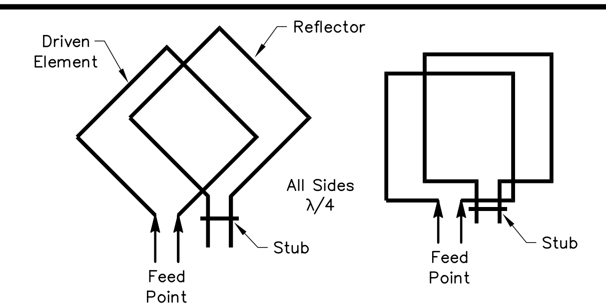

Fig 1—The basic two-element quad antenna, with driven loop and reflector loop. The driven loops are electrically one wavelength in circumference (1/4 wavelength on a side); the reflectors are slightly longer. Both configurations shown give horizontal polarization; for vertical polarization, the driven element should be fed at one of the side corners in the arrangement at the left, or at the center of a vertical side in the "square" quad at the right.

for quad antennas intended for operation below 30 MHz. At VHF, where the ratio of loop circumference to conductor diameter is usually relatively small, the circumference must be increased in comparison to the wavelength. For example, a one-wavelength loop constructed of $^{1}/_{4}$-inch tubing for 144 MHz should have a circumference about 2% greater than in the above equation for the driven element.

In any case, on-the-ground adjustment is required if optimum results are to be achieved, especially with respect to front-to-back ratio.

Element spacings on the order of 0.14 to 0.2 wavelength are generally used. The smaller spacings are usually employed in antennas with more than two elements, where the structural support for elements with larger spacings tends to become difficult. The feed-point impedances of antennas having element spacings on this order have been found to be in the 40- to 60-Ω range, so the driven element can be fed directly with coaxial cable at only a small mismatch. For spacings on the order of 0.25 wavelength (physically feasible for two elements, or for several elements at 28 MHz) the impedance more closely approximates the impedance of a driven loop alone (see Chapter 5)—that is, 80 to 100 Ω. The feed methods described in Chapter 26 can be used, just as in the case of the Yagi.

Directive Patterns and Gain

The small gain of a one-wavelength loop over a half-wave dipole also appears in arrays of loop elements. That is, if a quad parasitic array and a Yagi with the same boom length are compared, the quad will have approximately 2 dB more gain than the Yagi, as mentioned earlier. This assumes that both antennas have the optimum number of elements for the antenna length; the number of elements is not necessarily the same in both when the antennas are long.

CONSTRUCTION OF QUADS

The sturdiness of a quad is directly proportional to the quality of the material used and the care with which it is constructed. The size and type of wire selected for use with a quad antenna is important because it will determine the capability of the spreaders to withstand high winds and ice. One of the more common problems confronting the quad owner is that of broken wires. A solid conductor is more apt to break than stranded wire under constant flexing conditions. For this reason, stranded copper wire is recommended. For 14, 21 or 28-MHz operation, #14 or #12 wire is a good choice. Soldering of the stranded wire at points where flexing is likely to occur should be avoided.

Connecting the wires to the spreader arms may be accomplished in many ways. The simplest method is to drill holes through the fiberglass at the approximate points on the arms and route the wires through the holes. Soldering a wire loop across the spreader, as shown later, is recommended. However, care should be taken to prevent solder from flowing to the corner point where flexing could break it.

Dimensions for quad elements and spacing have been given in texts and *QST* over the years. **Table 1** is a collection of dimensions that will suit almost every amateur need for a quad system.

A boom diameter of 2 inches is recommended for systems having two or three elements for 14, 21 and 28 MHz. When the boom length reaches 20 feet or longer, as encountered in four- and five-element antennas, a 3-inch diameter boom is highly recommended. Wind creates two forces on the boom, vertical and horizontal. The vertical load on the boom can be reduced with a guy-wire truss cable. The horizontal forces on the boom are more difficult to relieve, so 3-inch diameter tubing is desirable.

Generally speaking, there are three grades of material which can be used for quad spreaders. The least expensive material is bamboo. Bamboo, however, is also the weakest material normally used for quad construction. It has a short life, typically only a few years, and will not withstand a harsh climate very well. Also, bamboo is heavy in contrast to fiberglass, which weighs only about a pound per 13-foot length. Fiberglass is the most popular type of spreader material, and will withstand normal winter climates. One step beyond the conventional fiberglass arm is the pole-vaulting arm. For quads designed to be used on 7 MHz, surplus “rejected” pole-vaulting poles are highly recommended. Their ability to withstand large amounts of bending is very desirable. The cost of these poles is high, and they are difficult to obtain. See Chapter 21 for dealers and manufacturers of spreaders.

Table 1
Quad Dimensions

Two-element quad (W7ZQ). Spacing given below; boom length given below.

	7 MHz	*14 MHz*	*21 MHz*	*28 MHz*
Reflector	144′11 1/2″	72′4″	48′8″	35′7″
Driven Element	140′11 1/2″	70′2″	47′4″	34′7″
Spacing	30′	13′	10′	6′6″
Boom Length	30′	13′	10′	6′6″
Feed Method	Directly with 23′ RG-11, then any length of RG-8 coax.	Directly with 11′7″ RG-11, then any length RG-8 coax.	Directly with 7′8 1/2″ RG-11, then any length RG-8 coax.	Directly with 5′8″ RG-11, then any length RG-8 coax.

(Note that a spider or boomless quad arrangement could be used for the 14/21/28-MHz parts of the above dimensions, yielding a triband antenna.)

Four-element quad* (WØAIW (14 MHz)/W7ZQ KØKKU/KØEZH/W6FXB). Spacing: equal, 10 ft; Boom length: 30 ft.**

	14 MHz Phone	*14 MHz CW*	*21 MHz*	*28 MHz*
Reflector	72′1 1/2″	72′5″	48′8″	35′8 1/2″
Driven Element	70′1 1/2″	70′5″	47′4″	34′8 1/2″
Director 1	69′1″	69′1″	46′4″	33′7 1/4″
Director 2	69′1″	69′1″	46′4″	33′7 1/4″
Feed Method	Directly with 52-Ω coax.	Directly with 52-Ω coax.	Directly with 52-Ω coax.	Directly with 5′9″ RG-11, then any length RG-8 coax.

*Common boom used to form a triband array.

**The two-element 7-MHz quad given above is added to form a four-band quad array.

Four-element quad (W7ZQ/K8DYZ*/K8YIB*/W7EPA*). Spacing: equal, 13′4″; Boom length: 40 ft.

	14 MHz	*21 MHz*	*28 MHz*
Reflector	72′5″	48′4″	35′8 1/2″
Driven Element	70′5″	47′0″	34′8 1/2″*
Director 1	69′1″	46′1″	(Directors 1-3 all 33′7″)*
Director 2	69′1″	46′1″	
Feed Method	Directly with 52-Ω coax.	Directly with 7′9″ RG-11, then any length 52-Ω coax.	Directly with 52-Ω coax.

*For the 28-MHz band, the driven element is placed between the 14/21-MHz reflector and 14/21-MHz driven element. The 28-MHz reflector is placed on the same frame as the 14/21-MHz reflectors and the remaining 28-MHz directors are placed on the remaining 14/21-MHz frames. The 28-MHz portion is then a 5-element quad.

Six-element quad (WØYDM, W7UMJ). Spacing: equal, 12 ft; Boom length: 60 ft.

	14 MHz
Reflector	72′1 1/2″
Driven Element	70′1 1/2″
Directors 1, 2 and 3	69′1″
Director 4	69′4″
Feed Method	Directly with 52-Ω coax.

A Three-Band Quad Antenna System

Quads have been popular with amateurs during the past few decades because of their light weight, relatively small turning radius, and their unique ability to provide good DX performance even when mounted close to the ground. A two-element, three-band quad, for instance, with the elements mounted only 35 feet above ground, will give good performance. **Fig 2** shows a large quad antenna which can be used as a design basis for either smaller or larger arrays.

Five sets of element spreaders are used to support the three-element 14-MHz, four-element 21-MHz, and five-element 28-MHz wire-loop system. The spacing between elements has been chosen to provide optimum performance consistent with boom length and mechanical construction. Each of the parasitic loops is closed (ends soldered together) and requires no tuning. All of the loop sizes are listed in **Table 2**, and are designed for center frequencies of 14.1, 21.1 and 28.3 MHz. Because quads are rather broadband antennas, excellent performance is obtained in both the CW and SSB band segments of each band (with the possible exception of frequencies above 29 MHz). Changing the dimensions to favor a frequency 200 kHz higher in each band to create a "phone" antenna is not necessary.

The most obvious problem related to quad antennas is the ability to build a structurally sound system. If high winds or heavy ice are a normal part of the environment, special precautions are necessary if the antenna is to survive a winter season. Another stumbling block for would-be quad builders is the installation of a three-dimensional system (assuming a Yagi has only two important dimensions) on top of a tower—especially if the tower needs guy wires for support. With proper planning, however, many of these obstacles can be overcome. For example, a tram system may be used.

An X or a + Frame?

One question which comes up quite often is whether to mount the loops in a diamond or a square configuration. In other words, should one spreader be horizontal to the earth, or should the wire be horizontal to the ground (spreaders mounted in the fashion of an X)? From the electrical point of view, it is probably a trade-off. Some authorities indicate that separation of the current points in the diamond system gives slightly more gain than is possible with a square layout. It should be pointed out, however, that there has not been any substantial proof in favor of one or the other, electrically.

From the mechanical point of view there is no question which version is better. The diamond quad, with the associated horizontal and vertical spreader arms, is capable of holding an ice load much better than a system where no vertical support exists to hold the wire loops upright. Put another way, the vertical poles of a diamond array, if sufficiently strong, will hold the rest of the system erect. When water droplets are accumulating and forming into ice, it is very reassuring to see water running down the wires to a corner and dripping off, rather than just sitting there on the wires and freezing. The wires of a loop (or several loops, in the case of a multiband antenna) help support the horizontal spreaders under a load of ice. A square quad will droop severely under heavy ice conditions because there is nothing to hold it up straight.

Table 2
Three-Band Quad Loop Dimensions

Band	*Reflector*	*Driven Element*	*First Director*	*Second Director*	*Third Director*
14 MHz	(A) 72′8″	(B) 71′3″	(C) 69′6″	—	—
21 MHz	(D) 48′6 1/2″	(E) 47′7 1/2″	(F) 46′5″	(G) 46′5″	—
28 MHz	(H) 36′2 1/2″	(I) 35′6″	(J) 34′7″	(K) 34′7″	(L) 34′7″

Letters indicate loops identified in Fig 3.

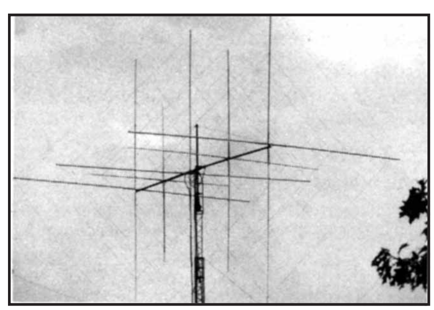

Fig 2—The three-band quad antenna.

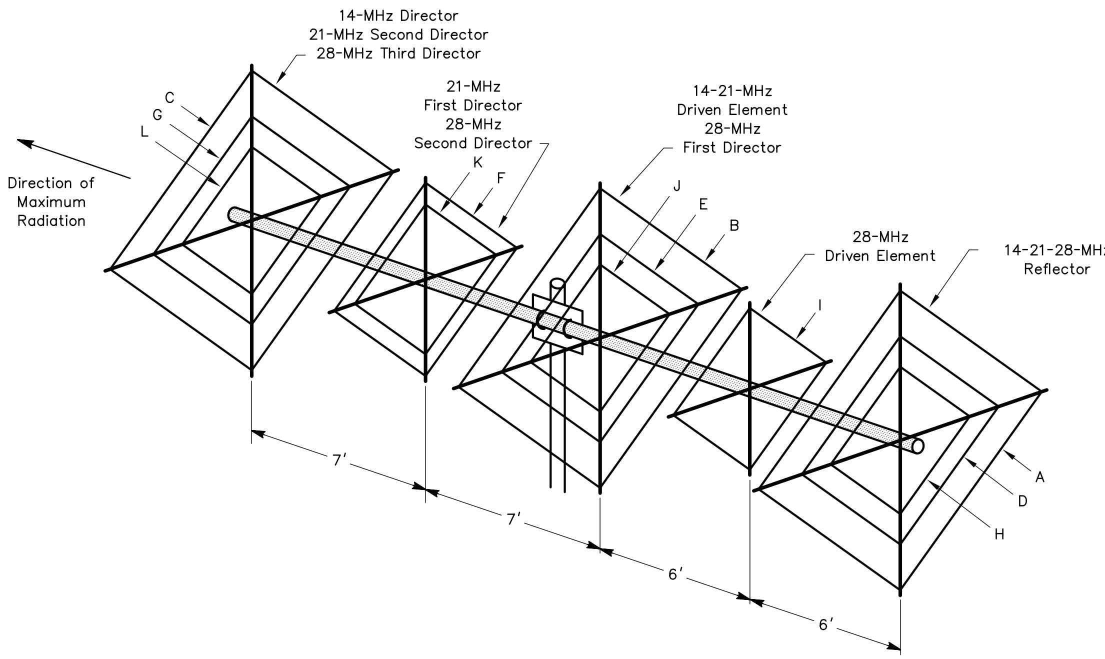

Fig 3—Dimensions of the three-band quad, not drawn to scale. See Table 2 for dimensions of lettered wires.

Another consideration enters into the selection of a design for a quad. The support itself, if guyed, will require a diamond quad to be mounted a short distance higher on the mast or tower than an equivalent square array if the guy wires are not to interfere with rotation.

The quad array shown in Fig 2 and **Fig 3** uses fiberglass spreaders (see Chapter 21 for suppliers). Bamboo is a suitable substitute (if economy is of great importance). However, the additional weight of the bamboo spreaders over fiberglass is an important consideration. A typical 12-foot bamboo pole weighs about 2 pounds; the fiberglass type weighs less than a pound. By multiplying the difference times 8 for a two-element array, times 12 for a three-element antenna, and so on, it quickly becomes apparent that fiberglass is worth the investment if weight is an important factor. Properly treated, bamboo has a useful life of three or four years, while fiberglass life is probably 10 times longer.

Spreader supports (sometimes called spiders) are available from many different manufacturers. If the builder is keeping the cost at a minimum, he should consider building his own. The expense is about half that of a commercially manufactured equivalent and, according to some authorities, the homemade arm supports described below are less likely to rotate on the boom as a result of wind pressure.

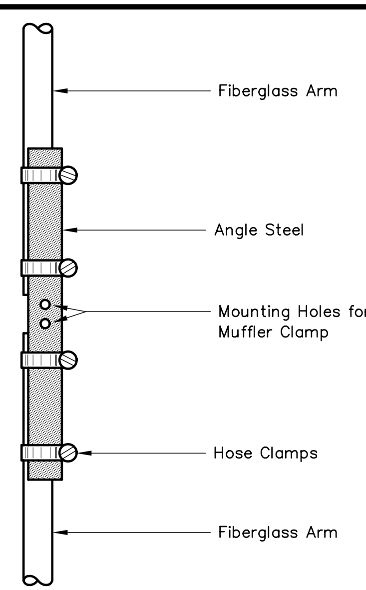

Fig 4—Details of one of two assemblies for a spreader frame. The two assemblies are jointed to form an X with a muffler clamp mounted at the position shown.

A 3-foot length of steel angle stock, 1 inch per side, is used to interconnect the pairs of spreader arms. The steel is drilled at the center to accept a muffler clamp of sufficient size to clamp the assembly to the boom. The fiberglass is attached to the steel angle stock with automotive hose clamps, two per pole. Each quad-loop spreader frame consists of two assemblies of the type shown in **Fig 4**.

Connecting the wires to the fiberglass can be done in a number of different ways. Holes can be drilled at the proper places on the spreader arms and the wires run through them. A separate wrap wire should be

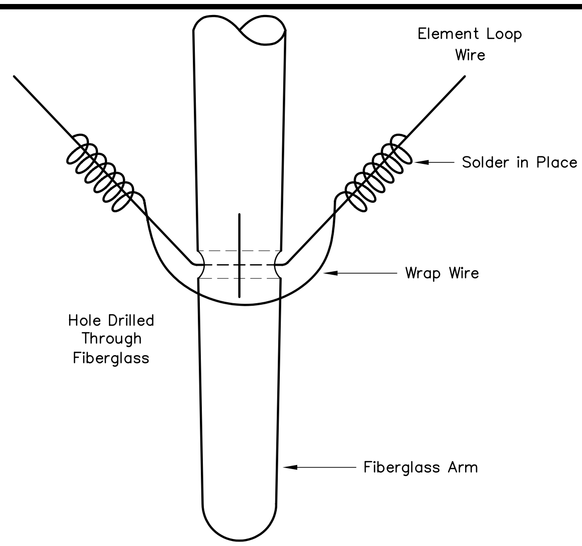

Fig 5—A method of assembling a corner of the wire loop of a quad element to the spreader arm.

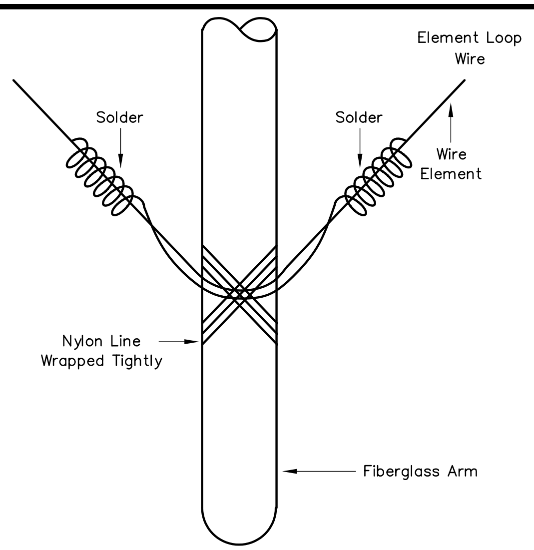

Fig 6—An alternative method of assembling the wire of a quad loop to the spreader arm.

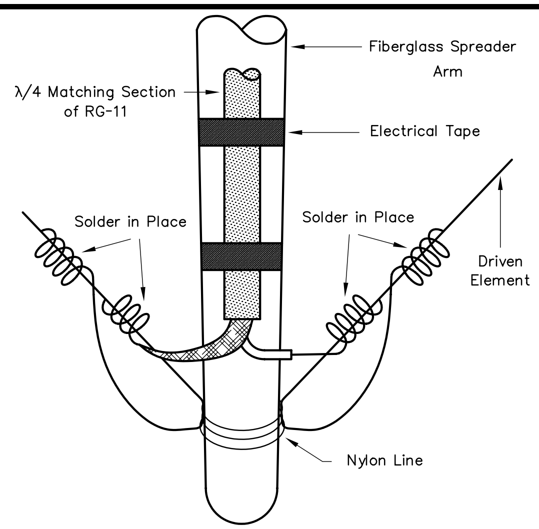

Fig 7—Assembly details of the driven element of a quad loop.

included at the entry/exit point to prevent the loop from slipping. Details are presented in **Fig 5**. Some amateurs have experienced cracking of the fiberglass, which might be a result of drilling holes through the material. However, this seems to be the exception rather than the rule. The model described here has no holes in the spreader arms; the wires are attached to each arm with a few layers of plastic electrical tape and then wrapped approximately 20 times in a criss-cross fashion with $^1/_8$-inch diameter nylon string, as shown in **Fig 6**. The wire loops are left open at the bottom of each driven element where the coaxial cable is attached. See **Fig 7**. All of the parasitic elements are continuous loops of wire; the solder joint is at the base of the diamond.

A triband system requires that each driven element be fed separately. Two methods are possible. First, three individual sections of coaxial cable may be used. Quarter-wave transformers of 75-Ω line are recommended for this service. Second, a relay box may be installed at the center of the boom. A three-wire control system may be used to apply power to the proper relay for the purpose of changing bands. The circuit diagram of a typical configuration is presented in **Fig 8** and its installation is shown in **Fig 9**. An alternative method of supplying a control signal to the remote switch is to make use of the feed line itself. Several articles on this subject have been published (see the Bibliography at the end of this chapter).

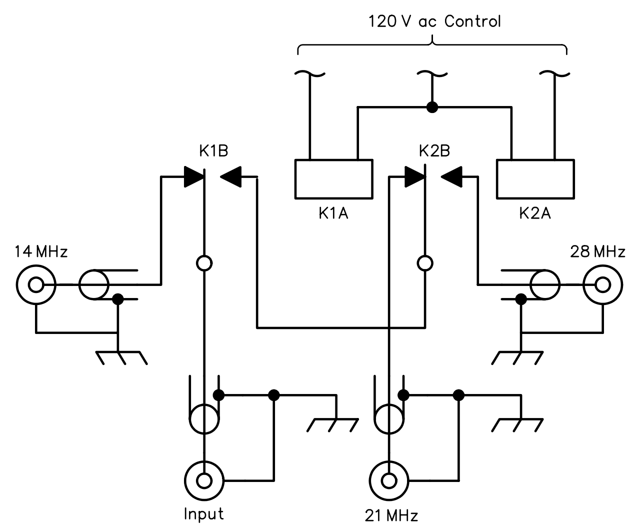

Fig 8—Suitable circuit for relay switching of bands for the three-band quad. A three-wire control cable is required. K1, K2—any type of relay suitable for RF switching, coaxial type not required (Potter and Brumfeld MR11A acceptable; although this type has double-pole contacts, mechanical arrangements of most single-pole relays make them unacceptable for switching of RF).

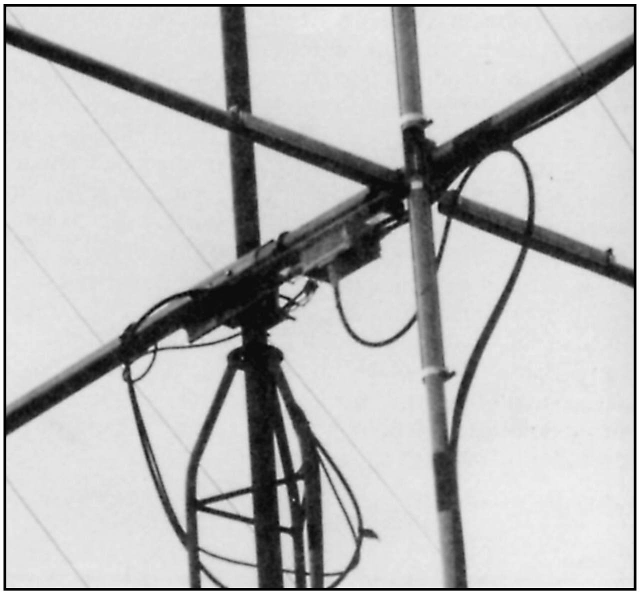

Fig 9—The relay box is mounted on the boom near the center. Each of the spreader-arm fiberglass poles is attached to steel angle stock with hose clamps.

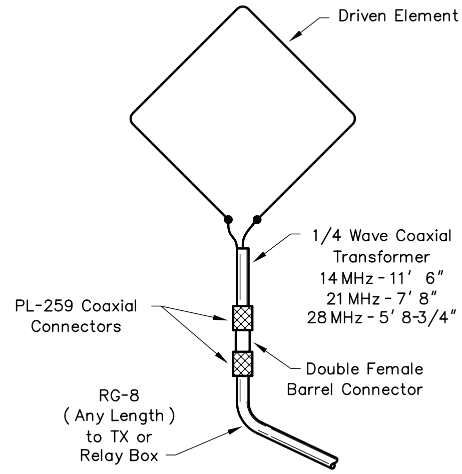

Fig 10—Installation of quarter-wave 75-Ω transformer section. The coax lengths indicated are based on a 66% velocity factor.

The quarter-wave transformers mentioned above are necessary to provide a match between the wire loop and a 52-Ω transmission line. This is simply a section of 75-Ω coax cable placed in series between the 52-Ω line and the antenna feed point, as shown in **Fig 10**. A pair of PL-259 connectors and a barrel connector may be used to splice the cables together. The connectors and the barrel should be wrapped well with plastic tape and then sprayed with acrylic for protection against the weather.

Every effort must be placed upon proper construction if freedom from mechanical problems is to be expected. Hardware must be secure or vibrations created by the wind may cause separation of assemblies. Solder joints should be clamped in place to keep them from flexing, which might fracture a connection point.

A 28-MHz Swiss Quad

The Swiss Quad is a two-element array with both elements driven. One element is longer than the other and is called the "reflector," while the shorter one is called the "director." Spacing between elements is usually 0.1 wavelength. The impedance of the antenna, using the 0.1-wavelength dimensions, is approximately 50 Ω.

Fig 11 is a drawing of the components of the beam. In its usual form, lengths of aluminum or copper tubing are bent to form the horizontal members. The element perimeters are completed with vertical wires. At the crossover points (X, Fig 11), which are connected together, voltage nodes occur.

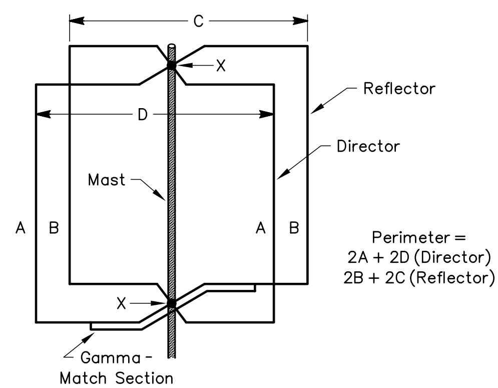

Fig 11—General arrangement for the Swiss Quad.

The equations for the element sizes are based on the square (perimeter) and not the lengths of the wires. For the reflector the perimeter is equal to 1.148 × wavelength, and for the director 1.092 × wavelength, or

$$\text{Perimeter (inches)} = \frac{984}{f(\text{MHz})} \times 12 \times 1.148 \text{ (reflector)}$$

For example:

$$\text{Perimeter for 28.1 MHz} = \frac{984}{28.1} \times 12 \times 1.148 = 482 \text{ in. (reflector)}$$

These equations apply only to the use of horizontal members of aluminum or copper tubing. Using PVC tubing and wire elements, the overall lengths of the perimeters are different and the correct lengths given later were determined experimentally.

One of the advantages of this antenna over the more conventional quad type is that plumber's delight type construction can be used. This means that both elements, at the top and bottom of the beam, can be grounded to the supporting mast. The structure is lightweight but strong, and an inexpensive TV rotator carries it nicely. Another feature is the small turning radius, which is less than half that of a three-element Yagi.

The antenna described here is made entirely of wire that is supported by two insulating frames constructed from rigid plastic water pipe. Rigid PVC water pipe is readily available from plumbing supply houses and from the large mail-order firms. The standard 10-foot lengths are just right for building the 28-MHz Swiss Quad. You can cut and drill PVC pipe with wood-working tools. PVC plastic sheds water, an advantage where winter icing is a problem. Heat from the intense summer sun has not softened or deformed the original quad structure.

To build the wire version of the Swiss Quad you will need the materials listed in **Table 3** plus some wood screws and U bolts. Also required are a few scraps of wood dowel rod and some old toothbrushes.

Cut the PVC pipe to the lengths shown in **Fig 12**. Also cut several short lengths of dowel rod for reinforcement at the points indicated. These are held in place by means of epoxy cement. The bond is improved if the PVC surface is roughened with sandpaper and wiped clean before the cement is applied. A tack inserted through a tiny hole in the pipe will hold each dowel in place while the epoxy cures.

Reasonable care is required in forming the boom end joints so the two sections of 3/4-inch pipe are parallel. The joining method used at WØERZ is illustrated in **Fig 13**. Parallel depressions were filed near each end of each boom with a half-round rasp. These cradles are about 0.4 inch deep and their centers are 41.3 inches apart. Holes are drilled for the U bolts and the joints are completed with the U bolts and the epoxy cement. Draw the bolts snug, but not so tight as to damage the PVC pipe. Final assembly of the insulating frames should be done on a level surface. Chalk an outline of the frame on the work surface so any misalignment will be easy to detect and correct. If the 1/2-inch pipe sections fit too loosely into the lateral members, shim them with two bands of masking tape before applying the epoxy cement.

Table 3
Materials List, Swiss Quad

Four 10-ft lengths 1/2-in. rigid PVC pipe.
Two 10-ft lengths 3/4-in. rigid PVC pipe.
One 10-ft length 1-in. rigid PVC pipe.
Twelve feet 1 1/8-in. or larger steel or aluminum tubing.
Epoxy cement (equal parts of resin and hardener).
100 ft hard-drawn copper wire, 14 or 16 gauge.

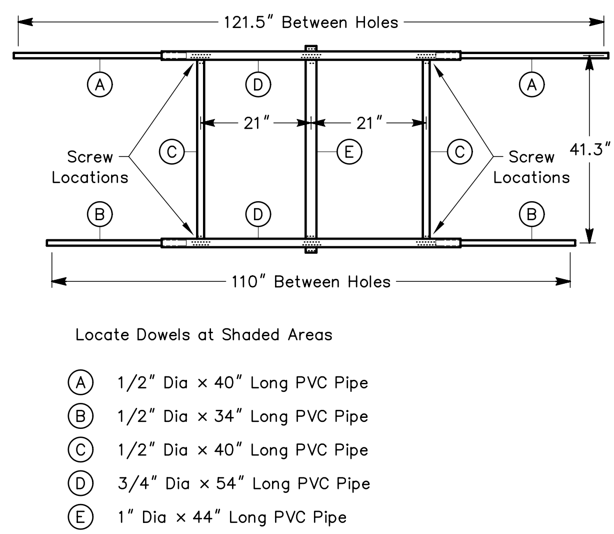

Fig 12—Dimensions and layout of the insulating frame.

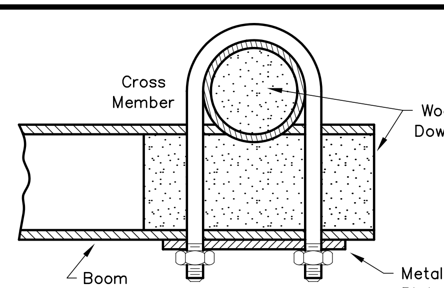

Fig 13—Boom end-joint detail.

Supports for the gamma-matching section can be made from old toothbrush handles or other scraps of plastic. Space the supports about 10 inches apart so that they support the gamma wire 2.5 inches on top of the lower PVC pipe. Attach the spacers with epoxy cement. Strips of masking tape can be used to hold the spacers in place while the epoxy is curing.

There are several ways to attach the frames to the vertical mast. The mounting hardware designed for the larger TV antennas should be quite satisfactory. Metal plates about 5 inches square can be drilled to accept four U bolts. Two U bolts should be used around the boom and two around the mast. A piece of wooden dowel inside the center of the boom prevents crushing the PVC pipe when the U bolts are tightened. The plates should not interfere with the element wires that must cross at the exact center of the frame. A 12-foot length of metal tubing serves as the vertical support. The galvanized steel tubing used as a top rail in chain link fences would be satisfactory.

When the epoxy resin has fully cured, you are ready to add the wire elements to produce the configuration shown in Fig 11. Start on the top side of the upper frame. Cut two pieces of copper wire (#14 or larger) at least 30.5 feet long and mark their centers. Thread the ends downward through holes spaced as shown in Fig 12 so that the wires cross at the top of the upper frame. Following the detail in **Fig 14**, drill pilot holes through the PVC pipe and drive four screws into the dowels. The screws must be 41.3 inches apart and equidistant from the center of the frame. With the centers of the two wires together, bend the wires 45° around each screw and anchor with a short wrap of wire. Now pull the wires through the holes at the ends of the pipes until taut. A soldered wire wrap just below each hole prevents the element wires from sliding back through the holes.

Attach the wired upper frame about 2 feet below the top of the vertical mast. Make a bridle from stout nylon cord (or fiberglass-reinforced plastic clothesline), tying it from the top of the mast to each of four points on the upper frame to reduce sagging.

Now cut two 11.5-foot lengths of wire and attach them to the bottom of the lower frame. Also cut a 9-foot length for the gamma-matching section. If insulated wire is used, bare 6 inches at each end of the gamma wire. Details of the double gamma match are shown in **Fig 15**. Attach the wired lower frame to the mast about 9 feet below the upper frame and parallel to it. The ultimate spacing between the upper and lower frames, determined during the tuning process, will result in moderate tension in the vertical wires. Join the vertical wires to complete the elements of your Swiss Quad. All vertical wires must be of equal length. Do not solder the wire joints until you have tuned the elements.

Tune-Up

For tuning and impedance matching you will need a dip meter, an SWR indicator, and the station receiver and exciter. Stand the Swiss Quad vertically in a clear space with the lower frame at least 2 feet above ground. Using the dipper as a resonance indicator, prune a piece of 52-Ω coaxial cable to an integral multiple of a half-wavelength at the desired frequency. RG-8 and RG-58 with polyethylene insulation have a velocity factor of 0.66. At 28.6 MHz, a half-wavelength section (made from the above cables) is approximately 11.35 feet long. (Coaxial cable using polyfoam insulation has a velocity factor of approximately 0.80; consult the manufacturer's data.) Connect one end to the midpoint of the gamma section and the other to a 2-turn link. Couple the dipper to the link. You may observe

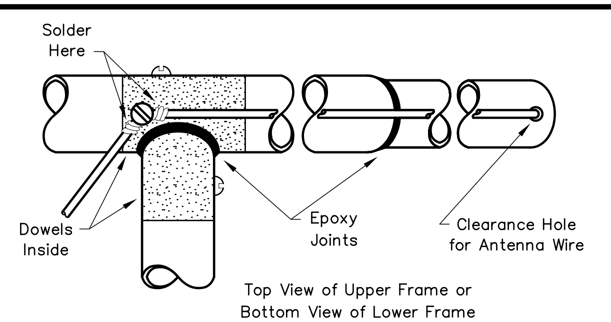

Fig 14—Details of the frame and wire assembly.

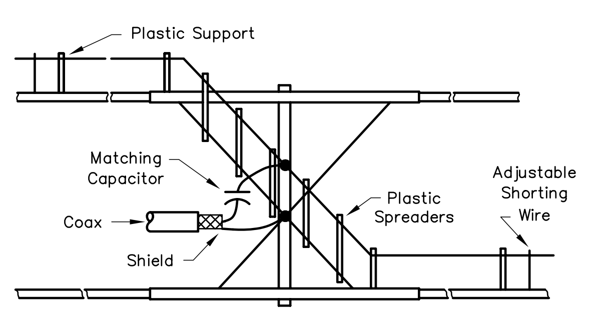

Fig 15—Details of the double gamma match.

several dips. Look for two pronounced dips, near 26 MHz and 31.4 MHz. Measure the frequencies at which these dips occur using your receiver to double-check the dip meter. Then multiply the frequencies and take the square root of this product; that is $\sqrt{f1 \times f2}$. If the result is less than 28.6, shorten the vertical wires equally and repeat the process until $\sqrt{f1 \times f2}$ lies between 28.6 MHz and 28.8 MHz. Your Swiss Quad is now tuned for the 28-MHz band.

Remove the link and connect the SWR bridge in its place. Connect your exciter to the input terminals of the bridge, tune to 28.6 MHz, and apply just enough power to obtain a full-scale forward power indication. Measure the SWR. Now slide the two shorting wires of the matching section to new positions, equidistant from the center of the wire elements, and measure the SWR. Continue adjusting the shorting wires until minimum SWR is obtained. Insert a 100-pF variable capacitor between the center conductor of the coaxial cable feeder and the midpoint of the gamma wire. Adjust the capacitor for minimum SWR indication. It may be necessary to readjust both the shorting wires and the capacitor to obtain a satisfactory impedance match. With patience, a perfect match (SWR = 1:1) can be achieved. Solder the shorting wires.

The variable capacitor may be replaced with a short length of RG-59 coaxial cable. Each foot of this cable has a capacitance of approximately 20 pF. Measure or estimate the value to which the variable capacitor was finally set, add 10%, and cut a corresponding length of RG-59. Solder the shield braid to the midpoint of the gamma wire and the center wire to the center conductor of the 52-Ω transmission line, leaving the other end of the coaxial-cable capacitor open. You will probably observe that the SWR has increased. Snip short lengths from the open end of the capacitor until the original low SWR is obtained. When the antenna is raised to 40 feet the SWR should be less than 1.5:1 over the entire 28-MHz band.

Tape the capacitor to the PVC pipe boom, then wrap a few bands of tape around the sections where the wires run along the sides of the pipes. Check the solder joints and mechanical connections. Coat the solder joints and the cable ends with a weatherproof sealing compound (such as silicone bathtub caulk or RTV sealant) and hoist the Swiss Quad up the support.

Multiband Spider-Delta Loop

The following is a description of a no-compromise, full-wave loop antenna that can be constructed for operation at 7, 10, 14, 18, 21, 24 or 28 MHz. The 14, 18, 21, 24 or 28-MHz versions are manageable enough that they can be positioned on a tower by two people, one on the tower, and one on the ground. (The second person is required mainly for safety reasons.) The four-band version (14 MHz and up, excluding 18 MHz) weighs about 50 pounds and is easily rotated with a Ham-M or equivalent rotator. This antenna was designed by Rich Guski, KC2MK, who has coined it the Spider-Delta Loop.

Measurements indicate that the gain and front-to-back ratio of this antenna are about the same as the conventional two-element quad. Depending on materials used and the number of bands covered, the cost of constructing this antenna should be far less than purchasing a comparable commercial antenna. The only complexity involved in building this antenna is the welding of steel angle stock for the spreaders.

The Spider-Delta Loop antenna is a hybrid of two familiar loop antenna designs, the two-element quad and the delta loop. Both antennas consist of two elements, one approximately 1-λ loop, used as a driven element, and another loop used as a reflector. The principal difference between the Spider-Delta Loop and a conventional quad is that the Spider uses triangular loops.

The traditional rotatable delta-loop antenna, which has a good reputation for DX performance, uses so-called plumber's delight construction. Two sides of the triangle loops consist of rigid material such as aluminum tubing. The apex formed by the two rigid sides is attached to a boom, which establishes the spacing between the loops. The third side of the triangle is made of wire. The triangles are normally oriented so the wire side is highest and parallel to the ground. The disadvantages of the delta- loop configuration are that the antenna is top-heavy, and it can be built for only one band. The Spider-Delta Loop overcomes these difficulties.

The loops of a quad antenna are usually made of wire, suspended by two sets of four arms (spreaders) made of rigid nonconducting material. The spreaders of a conventional quad are attached to a boom that, like the delta loop, establishes the spacing between the loops.

Additional sets of loops can be added to the spreaders for multiband operation, but in the conventional quad all such loops must have the same spacing, resulting in optimum element spacing for only one band. The gain, front-to-back ratio and radiation resistance of a two-element loop antenna are largely dependent on the spacing (in wavelengths) of the loops along the boom. The result, for the multiband conventional quad (with a boom) is a compromise for all but one of the bands covered by the antenna.

Another variation on the basic multielement loop antenna is the boomless quad, which offers an improvement over the conventional design. Instead of being supported by a boom, the spreaders are mounted at the center of the array and radiate outward. When viewed from the side of the array, the spreaders form two cones positioned point to point with the support mast between the points.

In a multiband boomless quad, the two longest elements (the elements for the lowest frequency of operation) are attached to the spreaders at the far ends. This positioning establishes the spacing of the two loops for that band. As the additional 1-λ loops for the other bands are attached to the spreaders, they will fit closer to the center of the array. The spacing of each of the shorter pairs of loops will be less than the spacing of the pair of longer loops. In this way it is possible to design a multiband two-element wire loop antenna for which all pairs of loops have the optimum spacing (in wavelengths), and still share the same spreaders.

The Spider-Delta Loop is a boomless design similar to the one described above, so the weight and wind-loading problems associated with a conventional antenna are reduced. Three spreaders per loop array are used here, rather than the four used in a conventional design. Two less spreaders are needed for the entire antenna when compared to the conventional quad.

The two-element loop antenna system described here has approximately 0.12-λ spacing for all bands. This spacing provides good front-to-back ratio and gain, and a feed-point impedance close to 50 Ω at resonance.

Dimensions

The Spider-Delta Loop lengths and spacing are derived from the standard quad-loop length equations presented earlier in this chapter. Spacing between the loops is 0.12 times the free-space wavelength in use.

The spreader length is calculated by using the results of the above calculations as the starting point. The spreader length is the distance between the center of the array and the loop apexes when the loops are in the shape of an equilateral triangle, in parallel planes, and spaced 0.12 λ apart. The array is balanced, so the junction of the spreaders is the mechanical center of mass of the antenna. This is shown in **Fig 16**.

All spreaders are the same length. The actual spreader length required for this antenna is that which is required to support the longest set of loops. This is a function of the lowest frequency band on which the antenna is designed to operate.

Table 4 contains the results of the above calculations for selected design frequencies within the 7, 10, 14, 18, 21, 24, and 28-MHz bands. If you prefer to design your antenna for different center frequencies, the dimensions can be scaled easily based on the information given in Table 4. As mentioned earlier, however, quad antennas are inherently broad.

All the driven loops share the same three spreader poles. Simi-

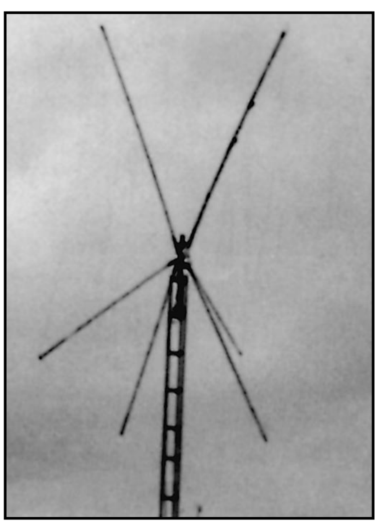

Fig 16—The Spider-Delta Loop in place on the tower at KC2MK.

Table 4
Loop and Spreader Lengths for Two-element Spider-Delta Loops
All dimensions are in feet.

Frequency (MHz)	7.175	10.125	14.175	18.100	21.250	24.930	28.600
Driven	140.07	99.26	70.90	55.52	47.29	40.31	35.14
Reflector	143.55	101.73	72.66	56.91	48.47	41.32	36.01
Spacing	16.50	11.70	8.36	6.54	5.58	4.75	4.14
Spreaders	28.83	20.43	14.59	11.43	9.74	8.30	7.23

larly, all the reflector loops for the array share the same three spreader poles. These conditions hold true regardless of the number of bands covered. For example, using the data in Table 4, the construction of a 5-band Spider-Delta Loop covering 14 through 29.7 MHz requires six spreaders, each approximately 14$^1/_2$ feet long.

Feed System

The two-element Spider-Delta Loop has a feed-point impedance of about 55 Ω at resonance. This provides a good match to common coaxial cable such as RG-8, RG-8X, or RG-58. The antenna may be fed directly by running separate cables to each driven element.

An alternative that offers a better directional pattern and improved front-to-back ratio is to use a separate balun for each of the driven-element feed points. The two-element triband version shown in Fig 16 uses this feed system. The baluns are homemade air-core transformers and are visible in the photographs. Refer to Chapter 26 for information on the construction and uses of balun transformers.

Materials

The mast used for the antenna shown in Fig 16 is a 2-inch steel pipe, 3 feet long, with the array attachments (described below) welded about 2 inches down from the top. Use the largest diameter steel mast that fits in your tower and rotator, to minimize the possibility of mast failure.

The two spider-to-mast attachments consist of steel angle stock 2 inches wide (on each side), and 7 inches long. These are welded directly to the mast as attachment points for the two spider halves. Two $^3/_8 \times$ 1-inch steel bolts are also required for each of the two array attachments.

The two spider halves are each made of six pieces of steel angle stock. One of these, which forms the base of a spider half, is 2 inches wide and 17 inches long. The other five are all 1$^1/_2$ inches wide. Three of these, which will become the spreader mounts, are 20 inches long. Another piece, used to brace the two lower spreader mounts, is 17 inches long. The upper spreader mount brace is 5 inches long.

Two $^3/_8$-inch diameter steel rods (or bolts), 5 inches long, are required to complete each of the spiders. They are needed to brace the lower spreaders.

The 14, 21 and 28-MHz Spider-Delta Loop shown in Fig 16 uses pole-vaulting poles for the spreaders. This antenna has survived years of ice and wind in the northeast. Although pole-vaulting poles or equivalent supports are required for a 7 or 10-MHz antenna, they are probably overkill for a 14 MHz or smaller antenna. Fiberglass poles suitable for use as spreaders are available from several companies (see Chapter 21).

The spreaders are attached to the spreader mounts on the spider with adjustable stainless-steel hose clamps. Three hose clamps are used to attach each of the six spreaders.

The loops are #14 copper-clad steel wire. The lengths of the loops can be adjusted and locked using electrician's copper wire clamps. **Table 5** lists the materials required to build a multiband Spider-Delta Loop antenna.

Table 5
Materials Required for Construction of the Spider-Delta Loop

Quantity/Material	*Application*
48 in. of 2 in. × 2 in. steel angle stock	Two 7-in. lengths for spider-to-mast attachment, two 17-in. lengths for spider half-bases.
164 in. of 1$^1/_2 \times$ 1$^1/_2$ in. steel angle stock	Six 20-in. lengths for spreader mounts, two 17-in. lengths for lower spreader braces, two 5-in. lengths for upper spreader braces.
Four $^3/_8$-in. diam × 1-in. steel bolts	Spider-to-mast attachments.
Four $^3/_8$-in. diam × 5-in. steel bolts or rods	Lower spreader braces.
18 stainless-steel hose clamps	Spreader to spreader-mount attachments.
Six fiberglass poles (see Table 4 for length)	Spreaders.
Copper-clad steel wire (see Table 4 for length)	Elements.
Several electrician's copper wire clamps	Element length adjustment. (Two per band required.)

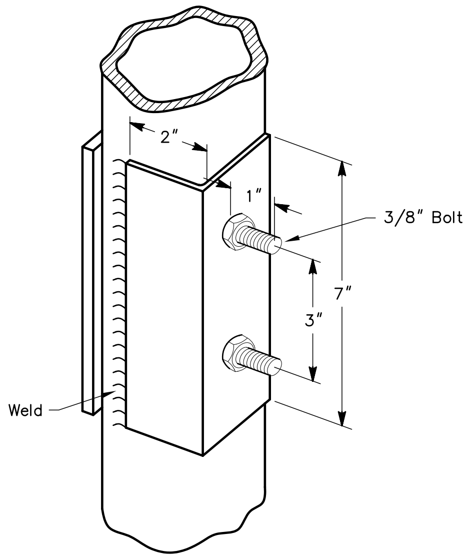

Fig 17—Diagram showing spider-mount attachments to the mast.

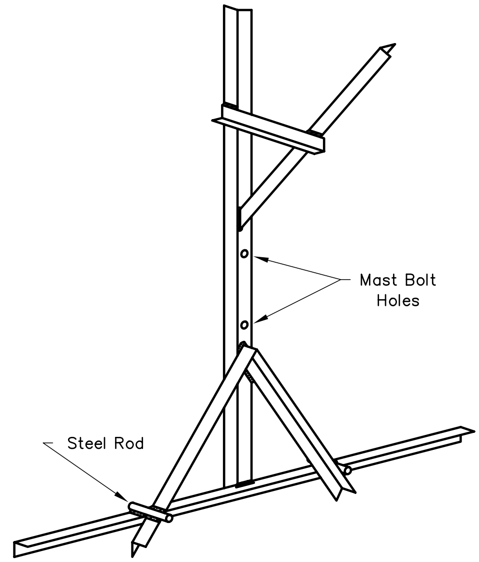

Fig 18—Layout of one of the two spider halves before attachment to the mast and spreader arms (not to scale).

Construction

The spider attachments are welded to the mast as shown in the diagram of **Fig 17**. A 7-inch piece of steel angle stock as described in the materials list is used to construct each of the two spider attachments. Four $^3/_8$-inch diameter steel bolts are permanently pinned between the angle stock and the mast with the bolt shafts facing outward through holes drilled in the angle stock. Carefully position the angle stock on the mast so the faces with the bolt holes are exactly opposite and parallel to each other. Be sure that you position the attachments high enough on the mast so the antenna will clear the tower when rotated. Weld each of the two pieces of angle stock to the mast along the entire length of the angle stock.

Center Spider Assembly

The center spider is constructed in two halves, one for the driven loop side and the other for the reflector side. This scheme permits raising the antenna one half at a time.

The two center spider halves are the structural heart of the antenna. Their construction is the most critical part of the project because they establish the shape and structural integrity of the antenna. They are made of steel angle stock and steel rods that are welded together to form the attachment points for the spreaders and the mast. Refer to **Fig 18** for the layout of the spider halves.

A 17-inch long piece of 2-inch wide angle stock is used as the base of each of the spiders. Two holes are drilled in the base of this piece to receive the $^3/_8$-inch bolts that are attached to the mast.

Refer to **Fig 19**. The upper spreader mount (as viewed from the favored direction of the antenna) is welded to the base immediately above the upper bolt hole. Be sure to leave enough room for the nut to clear the brace. The upper spreader mount is braced by a 5-inch piece of angle stock that is welded to the top of the spider base and to the spreader mount. The angle between the spider base and the spreader mount is 16.5°. This angle is important because it establishes the spacing for each

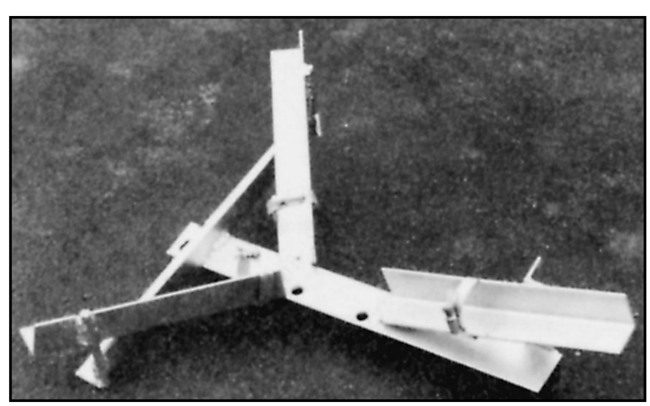

Fig 19—Photograph of one of the spider halves.

of the multiband loops which will be attached to the spreaders.

The lower spreader mounts are welded to the spider at a point immediately below the bolt holes. They are positioned so that they form an angle of 120° with the upper spreader mount and each other (as viewed from the favored direction of the antenna). A 17-inch long piece of steel angle stock is used as a brace for the lower spreader mounts. The center of this piece is welded to the lower end of the spider base, parallel to the plane of the loops and at a 90° angle to the spider base. The 5-inch steel rods are welded to the ends of the brace, perpendicular to it and away from the spider. The other ends of the 5-inch rods are welded to the two lower spreader mounts. The lower spreader mounts, like the upper spreader mounts, must be angled out at 16.5° from a plane containing the mast and perpendicular to the favored direction of the antenna.

It is a good idea to spot-weld the parts together first. Take time to test fit everything together. Bolt the spider halves to the mast and check all angles to make sure the antenna will have the proper shape and dimensions before completing the welding.

Attaching the Spreaders

Now attach three spreaders to the spider. The poles rest in each of the three spreader mounts and are fastened with steel hose clamps. Short pieces of pipe with the same outside diameter as the inside diameter of the fiberglass poles should be slipped inside the poles where they meet the mounts. (This is to prevent crushing of the poles with the hose clamps, and to add strength.)

Should it become necessary to replace a wire loop or access a feed point after the antenna has been installed, it is a simple matter to loosen the hose clamps holding the spreaders to their mounts, and pull the spreaders and wires close to the tower for service and adjustment. The antenna need be taken off the tower only for major servicing.

Cutting and Mounting the Wire Loops

With at least one half of the spiders and spreaders together, the wires for that side can be cut and fitted to the spreaders. The largest loop is attached to the poles first. Drill small holes through the poles to accept the wires. Depending on the poles used, you may want to use an alternative method of wire attachment, such as discussed earlier, especially if you are building a 7-MHz antenna and can make no compromises in structural strength.

Use the dimensions given in Table 4 to judge where on the spreaders to attach the wires. Cut each of the wires about 6 inches longer than the length shown in the table. This is to allow for tuning, which is done by adjusting the loop length where the wire ends meet and locking it with electrician's copper wire clamps. Refer to **Fig 20**. The wire clamps are located at the middle of the lower side of each of the loops. This makes the clamps accessible from the tower when the antenna is in place, as shown in **Fig 21**.

Feed Lines

Attach the feed lines to the driven loops where they attach to the upper spreader. The use of a balun at each feed point is optional. Each of the feed lines should be long enough to reach the center spider, with about 3 feet of excess. Terminate each cable with a PL-259.

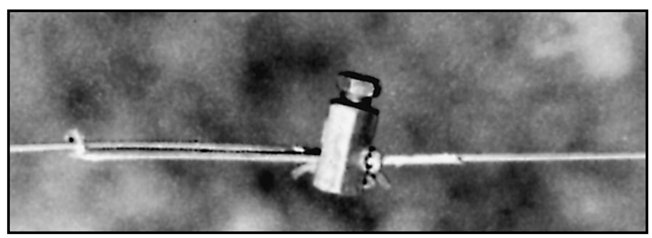

Fig 20—Close-up of one of the loop-length adjusting clamps used to tune the Spider-Delta Loop.

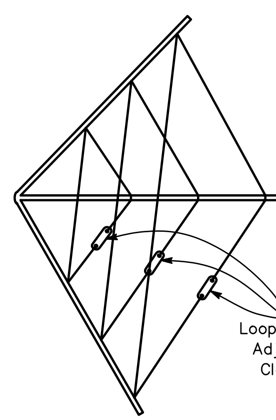

Fig 21—Diagram showing the placement of the loop-length adjusting clamps. Spider details are omitted for clarity. A triband version of the antenna is represented here.

The use of a remote antenna switch is optional. If used, it should be permanently attached to the spider of the driven half. The feed-line switch box is visible in Fig 16.

Raising the Antenna

Place the mast with the spider attachments on the tower first. Insert the mast in the rotator and then align the rotator direction indicator. Raise the antenna one half at a time. If your antenna is for 14 MHz or higher, one person on the tower can pull one side up at a time and lift it into place on the mast to spider attachment points. Tighten the bolts and install the other half of the antenna the same way. If you are raising a larger version, you will need a gin pole or a heavy-duty pulley attached to the mast.

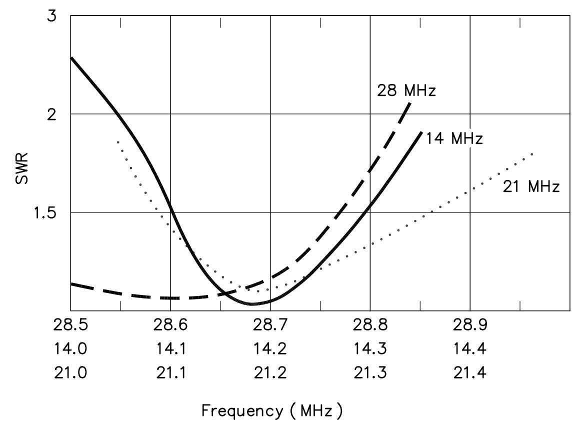

Fig 22—Typical SWR curves for the Spider-Delta Loop.

Tuning

The Spider-Delta Loop is tuned by lengthening or shortening the loops. Concentrating on one band at a time, adjust the driven loop for minimum SWR at the design frequency. Then adjust the reflector for the best SWR across the band. Alternatively, the reflector could be tuned for best gain or front-to-back ratio. The SWR curve of the Spider-Delta Loop is similar to that of the conventional quad antenna. **Fig 22** shows typical SWR curves for the version described here.

Future Considerations

One modification to this design that may be valuable is the construction of a feed system that allows switching of the physical location of the feed point from the apex to one of the lower corners. Feeding the antenna at a lower corner changes the polarization of the antenna from horizontal to diagonal, almost vertical.

BIBLIOGRAPHY

Source material and more extended discussions of the topics covered in this chapter can be found in the references given below and in the textbooks listed at the end of Chapter 2.

P. S. Carter, C. W. Hansell and N. E. Lindenblad, "Development of Directive Transmitting Antennas by R.C.A. Communications," *Proc. IRE*, Oct 1931.

C. Cleveland, "More'n One Way to Switch an Antenna," Technical Correspondence, *QST*, Nov 1986.

D. Cutter, "Simple Switcher," *73*, May 1980.

D. DeMaw, "A Remote Antenna Switcher for HF," *QST*, Jun 1986.

M. G. Knitter, Ed., *Loop Antennas—Design and Theory* (Cambridge, WI: National Radio Club, 1983).

J. Lindsay, "Quads and Yagis," *QST*, May 1968.

F. E. Terman, *Radio Engineering*, 3rd ed. (New York: McGraw-Hill Book Co, 1947).

E. M. Williams, "Radiating Characteristics of Short-Wave Loop Aerials," *Proc. IRE*, Oct 1940.