Editor's note: Section and figure references in this article are from the 2013 edition of the ARRL Handbook.

Five-Band, Two-Element HF Quad

Two quad designs are described in this article, both nearly identical. One was constructed by KC6T from scratch, and the other was built by Al Doig, W6NBH, using modified commercial triband quad hardware. The principles of construction and adjustment are the same for both models, and the performance results are also essentially identical. One of the main advantages of this design is the ease of (relatively) independent performance adjustments for each of the five bands. These quads were described by William A. Stein, KC6T, in *QST* for April 1992. Both models use 8-ft-long, 2-inch diameter booms, and conventional X-shaped spreaders (with two sides of each quad loop parallel to the ground).

These designs can also be simplified to monoband quads by using the formulas in Fig 21.77 for loop dimensions and spacing. It is recommended to the antenna builder unfamiliar with quads that a monoband quad be attempted first in order to become acquainted with the techniques of building a quad. Once comfortable with constructing and erecting the quad, success with a multiband design is much easier to achieve.

THE FIVE-BAND QUAD AS A SYSTEM

Unless you are extraordinarily lucky, you should remember one general rule: Any quad must be adjusted for maximum performance after assembly. Simple quad designs can be tuned by pruning and restringing the elements to control front-to-rear ratio and SWR at the desired operating frequency. Since each element of this quad contains five concentric loops, this adjustment method could lead to a nervous breakdown!

Fig 21.78 shows that the reflectors and driven elements are each independently adjustable. After assembly, adjustment is simple, and although gamma-match components on the driven element and capacitors on the reflectors add to the antenna's parts count, physical construction is not difficult. The reflector elements are purposely cut slightly long (except for the 10 meter reflector), and electrically shortened by a tuning capacitor. The driven-element gamma matches set the lowest SWR at the desired operating frequency.

As with most multiband directive antennas, the designer can optimize any two of the following three attributes at the expense of the third: forward gain, front-to-rear ratio and bandwidth (where the SWR is less than 2:1). These three characteristics are related, and changing one changes the other two. The basic idea behind this quad design is to permit (without resorting to trimming loop lengths, spacing or other gross mechanical adjustments):

- The forward gain, bandwidth and front-to-rear ratio may be set by a simple adjustment after assembly. The adjustments can be made on a band-by-band basis, with little or no effect on previously made adjustments on the other bands.
- Setting the minimum SWR in any portion of each band, with no interaction with previously made front-to-back or SWR adjustments.

The first of the two antennas described, the KC6T model, uses aluminum spreaders with PVC insulators at the element attachment points. (The author elected not to use fiberglass spreaders because of their high cost.) The second antenna, the W6NBH model, provides dimensions and adjustment values for the same antenna, but using standard tri-band quad fiberglass spreaders and hardware. If you have a tri-band quad, you can easily adapt it to this design. When W6NBH built his antenna, he had to shorten the 20 meter reflector because the KC6T model uses a larger 20 meter reflector than W6NBH's fiberglass spreaders would allow. Performance is essentially identical for both models.

MECHANICAL CONSIDERATIONS

Even the best electrical design has no value if its mechanical construction is lacking. Here are some of the things that contribute to mechanical strength: The gamma-match capacitor KC6T used was a small, air-variable, chassis-mount capacitor mounted in a plastic box (see **Fig 21.79**). A male UHF connector was mounted to the box, along with a screw terminal for connection to the gamma rod. The terminal lug and wire are for later connection to the driven element. The box came from a local hobby shop, and the box lid was replaced with a piece of 1⁄32-inch ABS plastic, glued in place after the capacitor, connector and wiring had been installed. The capacitor can be adjusted with a screwdriver through an access hole. Small vent (drain) holes were drilled near corresponding corners of each end.

Enclose the gamma-match capacitor in such a manner that you can tape unwanted

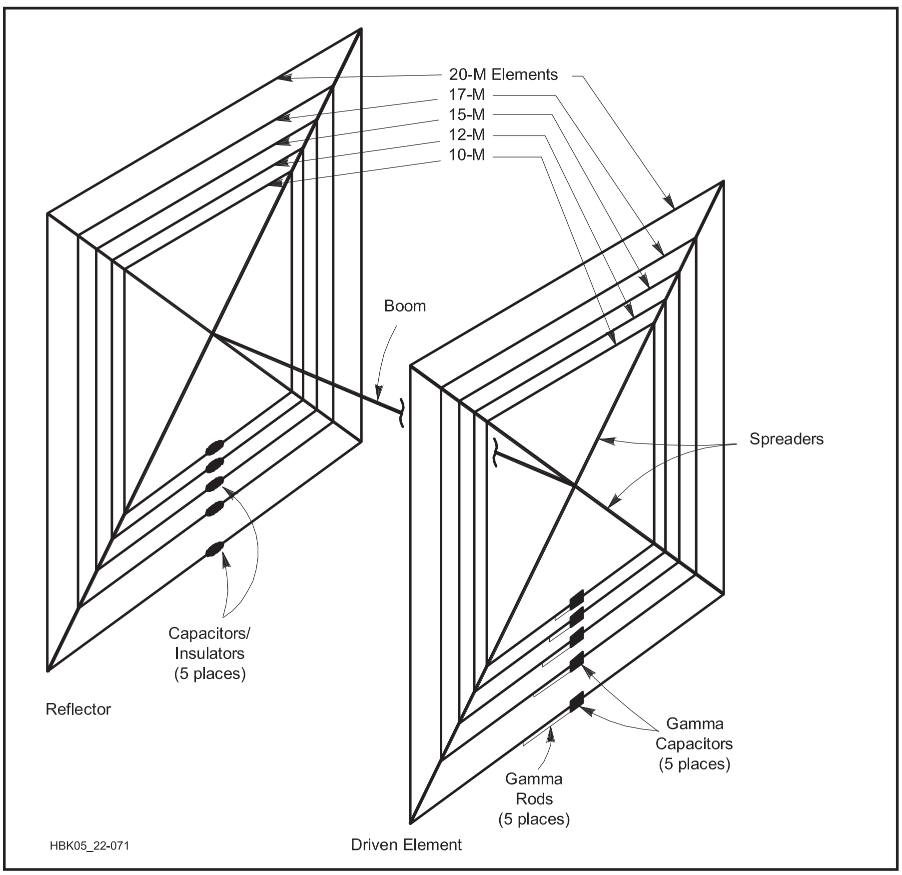

Fig 21.78 — Mechanical layout of the five-band quad. The boom is 8 ft long; see Table 21.16 for all other dimensions.

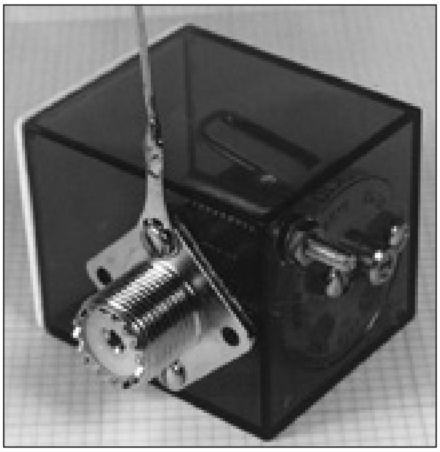

Fig 21.79 — Photo of one of the feed point gamma-match capacitors.

Table 21.16
Element Lengths and Gamma-Match Specifications of the KC6T and W6NBH Five-Band Quads

KC6T Model

	Driven	------Gamma Match-----			Reflector	
Band (MHz)	*Element Length (in)*	*Length (in)*	*Spacing (in)*	*C_g (pF)*	*Length (in)*	*C_R (pF)*
14	851.2	33	2	125	902.4	68
18	665.6	24	2	110	705.6	47
21	568	24	1.5	90	604.8	43
24.9	483.2	29.75	1	56	514.4	33
28	421.6	26.5	1	52	448.8	(jumper)

W6NBH Model

	Driven	-----Gamma Match------			Reflector	
Band (MHz)	*Element Length (in)*	*Length (in)*	*Spacing (in)*	*C_g (pF)*	*Length (in)*	*C_R (pF)*
14	851.2	31	2	117	890.4	120
18	665.6	21	2	114	705.6	56
21	568	26	1.5	69	604.8	58
24.9	483.2	15	1	75.5	514.4	54
28	421.6	18	1	41	448.8	(jumper)

openings closed so that moisture can't be directly blown in during wind and rainstorms. Also, smaller boxes and sturdy mounts to the driven element ensure that you won't pick up gamma capacitor assemblies along with the leaves after a wind storm.

Plastic gamma-rod insulators/standoffs were made from 1⁄32-inch ABS, cut ½-inch wide with a hole at each end. Use a knife to cut from the hole to the side of each insulator so that one end can be slipped over the driven element and the other over the gamma rod. Use about four such insulators for each gamma rod, and mount the first insulator as close to the capacitor box as possible. Apply five-minute epoxy to the element and gamma rod at the insulator hole to keep the insulators from sliding. If you intend to experiment with gamma-rod length, perform this gluing operation after you have made the final gamma-rod adjustments.

ELEMENT INSULATORS

As shown in Fig 21.78, the quad uses insulators in the reflectors for each band to break the loop electrically, and to allow reflector adjustments. Similar insulators were used to break up each driven element so that element impedance measurements could be made with a noise bridge. After the impedance measurements, the driven-element loops are closed again. The insulators are made from ¼ × 2 × ¾-inch phenolic stock. The holes are ½-inch apart. Two terminal lugs (shorted together at the center hole) are used in each driven element. They offer a convenient way to open the loops by removing one screw. **Fig 21.80** shows these insulators and the gamma-match construction schematically. **Table 21.16** lists the component values, element lengths and gamma-match dimensions.

ELEMENT-TO-SPREADER ATTACHMENT

Probably the most common problem with quad antennas is wire breakage at the element-to-spreader attachment points. There are a number of functional attachment methods; **Fig 21.81** shows one of them. The attachment method with both KC6T and W6NBH spreaders is the same, even though the spreader constructions differ. The KC6T model uses #14 AWG, 7-strand copper wire; W6NBH used #18 AWG, 7-strand wire. At the point of element attachment (see **Fig 21.82**), drill a hole through both walls of the spreader using a #44 (0.086-inch) drill. Feed a 24-inch-long piece of antenna wire through the hole and center it for use as an attachment wire.

After fabricating the spider/spreader assembly, lay the completed assembly on a flat surface and cut the element to be installed to the correct length, starting with the 10 meter element. Attach the element ends to the insulators to form a closed loop before attaching the elements to the spreaders. Center the insulator between the spreaders on what will become the bottom side of the quad loop, then carefully measure and mark the element-mounting-points with fingernail polish (or a similar substance). Do *not* depend on the

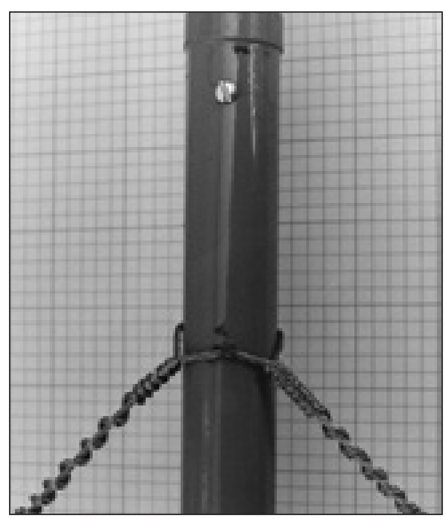

Fig 21.81 — Attaching quad wires to the spreaders must minimize stress on the wires for best reliability. This method (described in the text) cuts the chances of wind-induced wire breakage by distributing stress.

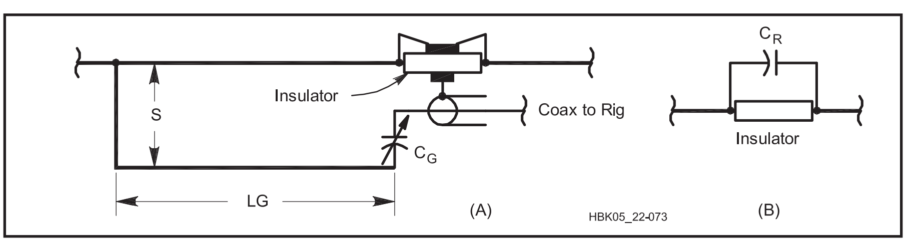

Fig 21.80 — Gamma-match construction details at A and reflector-tuning capacitor (CR) attachment schematic at B. The gamma matches consist of matching wires (one per band) with series capacitors (Cg). See Table 21.16 for lengths and component specifications.

at-rest position of the spreaders to guarantee that the mounting points will all be correct.

Holding the mark at the centerline of the spreader, tightly loop the attachment wire around the element and then gradually space out the attachment-wire turns as shown. The attachment wire need not be soldered to the element. The graduated turn spacing minimizes the likelihood that the element wire will flex in the same place with each gust of wind, thus reducing fatigue-induced wire breakage.

FEEDING THE DRIVEN ELEMENTS

Each driven element is fed separately, but feeding five separate feed lines down the tower and into the shack would be costly and mechanically difficult. The ends of each of these coax lines also require support other than the tension (or lack of thereof) provided by the driven element at the feed point. It is best to use a remote coax switch on the boom approximately 1 ft from the driven-element spider-assembly attachment point.

If the gamma match is used, the cables connecting the gamma-match capacitors and the coax switch help support the driven elements and gamma capacitors. The support can be improved by taping the cables together in several places. A single coaxial feed line (and a control cable from the remote coax switch, if yours requires one) is the only required cabling from the antenna to the shack.

If the synchronous transmission line transformer is used, the ¼-wavelength of cable required is of convenient lengths that allow a remote antenna switch to be mounted on the antenna boom and the matching sections connected between the switch and driven elements. The drawback of the matching section technique is that it is not easily adjustable.

THE KC6T MODEL'S COMPOSITE SPREADERS

If you live in an area with little or no wind, spreaders made from wood or PVC are practical, but if you live where winds can reach 60 to 80 mi/h, strong, lightweight spreaders are a must. Spreaders constructed with electrical conductors (in this case, aluminum tubing) can cause a myriad of problems with unwanted resonances, and the problem gets worse as the number of bands increases.

To avoid these problems, this version uses composite spreaders made from machined PVC insulators at the element-attachment points. Aluminum tubing is inserted into (or over) the insulators 2 inches on each end. This spreader is designed to withstand 80 mi/h winds. The overall insulator length is designed to provide a 3-inch center insulator clear of the aluminum tubing. The aluminum tubing used for the 10 meter section (inside dimension "A" in Fig 21.82) is 1⅛-inch diameter × 0.058-inch wall. The next three sections are ¾-inch diameter × 0.035-inch wall, and the outer length is made from ½-inch diameter × 0.035-inch wall. The dimensions shown in Fig 21.82 are *attachment point* dimensions only.

	Dim	Driven	Reflector
	A	74.5	79.4
	B	85.4	90.9
	C	100.4	106.9
	D	117.6	124.7
KC6T:	E	150.4	159.5
W6NBH:	E	150.4	157.4

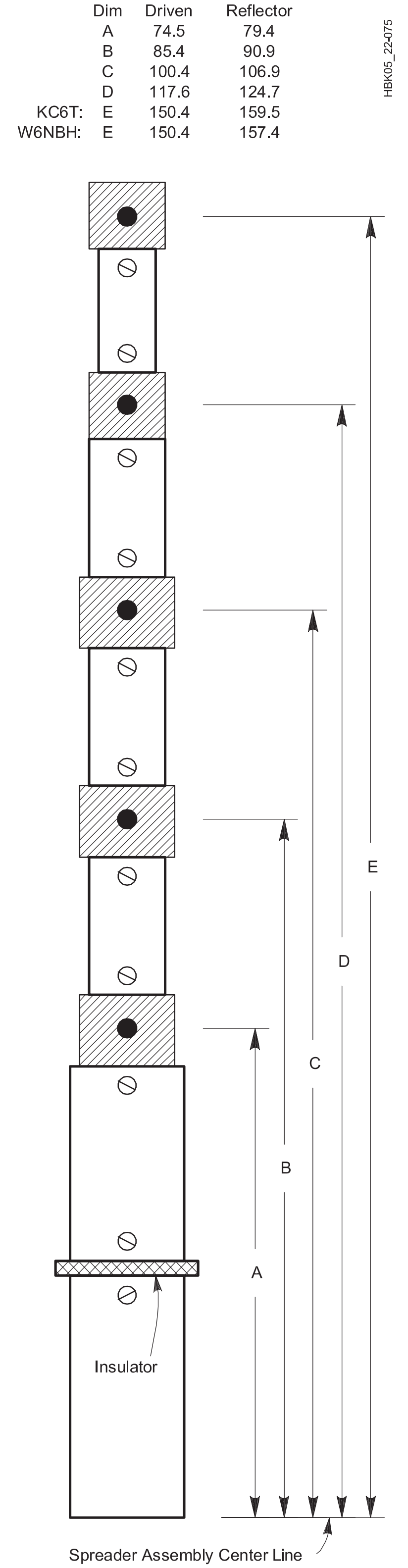

Fig 21.82 — Spreader-drilling diagram and dimensions (in.) for the five-band quad. These dimensions apply to both spreader designs described in the text, except that most commercial spreaders are only a bit over 13 ft (156 inches) long. This requires compensation for the W6NBH model's shorter 20 meter reflector as described in the text.

Attach the insulators to the aluminum using #6 sheet metal screws. Mechanical strength is provided by Devcon no. S 220 Plastic Welder Glue (or equivalent) applied liberally as the aluminum and plastic parts are joined. Paint the PVC insulators before mounting the elements to them. Paint protects the PVC from the harmful effects of solar radiation. As you can see from Fig 21.82, an additional spreader insulator located about halfway up the 10 meter section (inside dimension "A") removes one of the structure's electrical resonances not eliminated by the attachment-point insulators. Because it mounts at a relatively high-stress point in the spreader, this insulator is fabricated from a length of heavy-wall fiberglass tubing.

Composite spreaders work as well as fiberglass spreaders, but require access to a well-equipped shop, including a lathe. The main objective of presenting the composite spreader is to show that fiberglass spreaders aren't a basic requirement — there are many other ways to construct usable spreaders. If you can lay your hands on a used multiband quad, even one that's damaged, you can probably obtain enough spreaders to reduce construction costs considerably.

GAMMA ROD

The gamma rod is made from a length of #12 AWG solid copper wire (W6NBH used #18 AWG, 7-strand wire). Dimensions and spacings are shown in Table 21.16. If you intend to experiment with gamma-rod lengths and capacitor settings, cut the gamma-rod lengths about 12 inches longer than the length listed in the table. Fabricate a sliding short by soldering two small alligator clips back-to-back such that they can be clipped to the rod and the antenna element and easily moved along the driven element. Note that gamma-rod spacing varies from one band to another. When you find a suitable shorting-clip position, mark the gamma rod, remove the clip, bend the gamma rod at the mark and solder the end to the element.

THE W6NBH MODEL

As previously mentioned, this model uses standard 13-ft fiberglass spreaders, which aren't quite long enough to support the larger 20 meter reflector specified for the KC6T model. The 20 meter W6NBH reflector loop is cut to the dimensions shown in Table 21.16, 12 inches shorter than that for the KC6T model. To tune the shorter reflector, a six-inch-long stub of antenna wire (conductors spaced two inches) hangs from the reflector insulator, and the reflector tuning capacitor mounts on another insulator at the end of this stub.

GAMMA-MATCH AND REFLECTOR-TUNING CAPACITOR

Use an air-variable capacitor of your choice for each gamma match. Approximately 300 V can appear across this capacitor (at 1500 W), so choose plate spacing appropriately. If you want to adjust the capacitor for best match and then replace it with a fixed capacitance, remember that several amperes of RF will flow through the capacitance. If you choose disc-ceramic capacitors, use a parallel combination of at least four l-kV units of equal value. Any temperature coefficient is acceptable. NP0 units are not required. Use similar components to tune the reflector elements.

ADJUSTMENTS

Well, here you are with about 605 ft of wire. Your antenna will weigh about 45 pounds (the W6NBH version is slightly lighter) and have about nine square ft of wind area. If you chose to, you can use the dimensions and capacitance values given, and performance should be excellent. If you adjust the antenna for minimum SWR at the band centers, it should cover all of the lower four bands and 28 to 29 MHz with SWRs under 2:1; front-to-back ratios are given in **Table 21.17**.

Instead of building the quad to the dimensions listed and hoping for the best, you can adjust your antenna to account for most of the electrical environment variables of your installation. The adjustments are conceptually simple: First adjust the reflector's electrical length for maximum front-to-rear ratio (if you desire good gain, and are willing to settle for a narrower than maximum SWR bandwidth), or accept some compromise in front-to-rear ratio that results in the widest SWR bandwidth. You can make this adjustment by placing an air-variable capacitor (about 100-pF maximum) across the open reflector loop ends, one band at a time, and adjusting the capacitor for the desired front-to-rear ratio. The means of doing this will be discussed later.

During these reflector adjustments, the driven-element gamma-match capacitors may be set to any value and the gamma rods may be any convenient length (but the sliding-short alligator clips should be installed somewhere near the lengths specified in Table 21.16). After completing the front-to-rear adjustments, the gamma capacitors and rods are adjusted for minimum SWR at the desired frequency.

ADJUSTMENT SPECIFICS

Make a calibrated variable capacitor (with a hand-drawn scale and wire pointer). Calibrate the capacitor using your receiver, a known-value inductor and a grid-dip meter (plus a little calculation) or SWR analyzer.

Adjust each band by feeding it separately if the gamma match technique is used. If transmission line matching sections are used, they must all be connected to the remote switch when adjusting the antenna because each unused section acts as a short coaxial stub, adding reactance at the connection to the antenna.

To adjust front-to-back ratio, simply clip the (calibrated) air-variable capacitor across the open ends of the desired reflector loop. Connect the antenna to a portable receiver with an S meter. Point the back of the quad at a signal source, and slowly adjust the capacitor for a dip in the S-meter reading.

After completing the front-to-back adjustments, replace the variable capacitor with an appropriate fixed capacitor and seal the connections against the weather. Then move to the driven-element adjustments. Connect the coax through the SWR bridge to the 10 meter gamma-match capacitor box. Use an SWR bridge that requires only a watt or two (not more than 10 W) for full-scale deflection in the calibrate position on 10 meters. Using the minimum necessary power, measure the SWR. Go back to receive and adjust the capacitor until (after a number of transmit/receive cycles) you find the minimum SWR. If it is too high, lengthen or shorten the gamma rod by means of the sliding alligator-clip short and make the measurements again.

Stand away from the antenna when making transmitter-on measurements. The adjustments have minimal effect on the previously made front-to-rear settings, and may be made in any band order. After making all the adjustments and sealing the gamma capacitors, reconnect the coax harness to the remote coax switch.

Adjusting the SWR when using transmission-line matching sections requires first measuring the impedance of each loop at the feed point. To avoid standing next to the antenna while making the measurement, connect the test equipment to the antenna using a ½-λ piece of transmission line of any characteristic impedance. Cut a ¼-λ section of transmission line with an appropriate impedance a few percent longer than the exact value. Attach the matching section to the loop feed point. Measure the resulting impedance at the output of the matching section and trim its length to place the minimum SWR point at the desired frequency. Using this technique, it is not likely that an SWR of 1:1 can be obtained, but values below 1.5:1 should be attainable.

Table 21.17
Measured Front-to-Back Ratios

Band	*KC6T Model*	*W6NBH Model*
14	25 dB	16 dB
18	15 dB	10 dB
21	25 dB	>20 dB
24.9	20 dB	>20 dB
28	20 dB	>20 dB