The Pfeiffer Quad Antenna System

Here's how you can shrink a standard quad and wind up with a no-compromise antenna. Build one and prove it to yourself!

By Andy Pfeiffer, K1KLO
132 Whippoorwill Rd
Old Lyme, CT 06371

Over the years, I built many Yagi antennas and, until recently, had three homemade monoband Yagis in service. I had avoided experimenting with quads after seeing the sad remains of one visited by a New England wind and ice storm. (Here in Old Lyme, at the mouth of the Connecticut River, we have our share of winter storms and hurricanes.) Although the quad is an excellent performer, to many hams it's a three-dimensional nightmare. It's physically difficult to maneuver and *prone to destruction when subjected to the* violent forces of nature. No more.

Design History

In April 1991, I dismantled my home-brew, 12-meter, three-element monoband Yagi and decided I'd attempt to shrink the quad so it would no longer be hurricane bait. The quads I'm about to describe are small and mechanically rugged. They'll weather anything the elements can hurl against them—and do so without any noticeable loss in performance. Therefore, I've permanently retired my Yagis!

My 12-meter Maltese Quad (so named for its resemblance to the Maltese cross) has been in constant service for over two years. A second Maltese Quad, built and erected about one year ago, replaced a *home-brew, three-element, 17-meter* monoband Yagi, and is as effective as its 12-meter forerunner. Being unable to let go of the tiger's tail, I designed and built a *third* Maltese Quad (this one for 20 meters) modified such that it *further* reduces the size of the antenna, compared to a standard quad frame.

Design Approach

It's not difficult to design and build an antenna physically smaller than normal: Loading coils and traps can do the trick. Using them, however, introduces losses. To me, that approach is a waste of time and effort. I don't want a compromise antenna. In lieu of coils and capacitors, I chose to use linear loading.

Standard Maltese Quad

During the following discussion, refer to Figures 1 to 5. In Figure 1, the outer square represents the wire perimeter of the driven element of a 12-meter standard-size quad driven element. Using the formula $250 \div f_{MHz}$ for one side of the square, and a *center frequency of 24.940 MHz, each side* (S) is 10 feet long. This equates to a spreader diagonal (the distance from point A to point B) of 14 feet 2 inches. The Maltese Quad (inner drawing) has a spreader diagonal length (point C to point D) of only 8 feet! (The spreaders have been omitted from Figure 1 to maintain drawing clarity.)

For a standard 20-meter quad and a center frequency of 14.175 MHz, each side in Figure 1 is about 18 feet long. This translates to a spreader diagonal, A to B, of 25 feet 5 inches. By comparison, the Maltese Quad has a spreader diagonal of only 14 feet! This clearly shows the considerable size reduction obtained by using linear loading.

A Double-Cross

The perimeter of a standard 20-meter

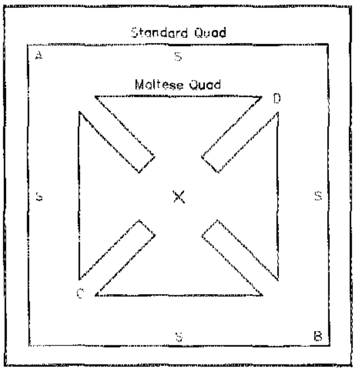

Figure 1—The outer square is the wire perimeter of a standard-size-quad driven element for the 12-meter band. Using the formula $250 \div f_{MHz}$ for one side of the square, and a center frequency of 24.940 MHz, each side is 10 feet long. This translates to a spreader diagonal (A-B) *of 14 feet 2 inches. The inner* configuration defines the wire perimeter of the Maltese Quad. It's drawn to the same scale, but has a spreader diagonal (C-D) of only 8 feet. This indicates the respectable size reduction obtained by the linear-loading approach. (The spreaders have been omitted from this drawing to maintain clarity.)

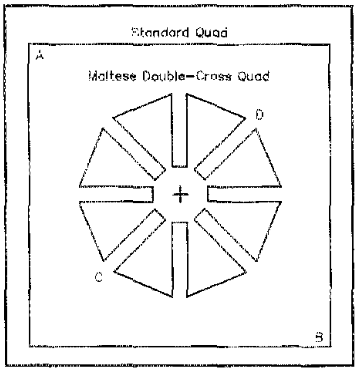

Figure 2—The perimeter wiring of a standard 20-meter quad driven element. The inner configuration (that of the Maltese Double-Cross Quad) is of a wheel with eight spokes (eight spreaders). Its spreader diagonal, C-D, is a mere 10 feet 4 inches compared to the 25-foot diagonal of the standard 20-meter quad!

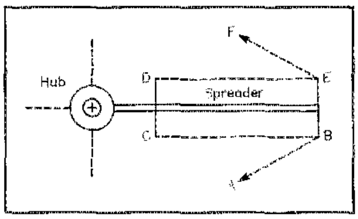

Figure 3—Here's a single spreader with the two yardarms in position. The dashed lines, A-F, indicate the course of the Maltese-Quad perimeter wire. E-B is the fiberglass rod; C-D is the aluminum rod. (The mechanical layout and the wiring of the reflector element is identical to that of the driven element.)

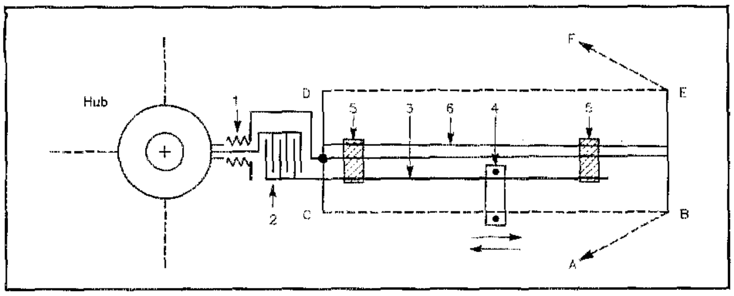

Figure 4—Drawing of the gamma match used with all of the Maltese Quads. Although some of the components used in the gamma match may seem esoteric, they are materials I have on hand. Other Maltese Quad builders have substituted other materials without detrimental effect. (1) is an SO-239 connector for attachment of the coaxial-cable feed line; (2) is an air-variable capacitor; (3) is the gamma rod, made of a length of 1/8-inch-diameter copper wire; (4) is the match's adjustable bar, also made of copper; (5) are supports for the gamma rod (made of Lexan polycarbonate); (6) is the fiberglass spreader arm of the quad. The gamma match is adjusted by tuning the variable capacitor and moving the adjusting bar (4), which slides over the gamma rod and bottom wire (C-B) of the linear-loading section. Refer to *The ARRL Antenna Book* or *The ARRL Handbook* for more information on the gamma match and its adjustment.

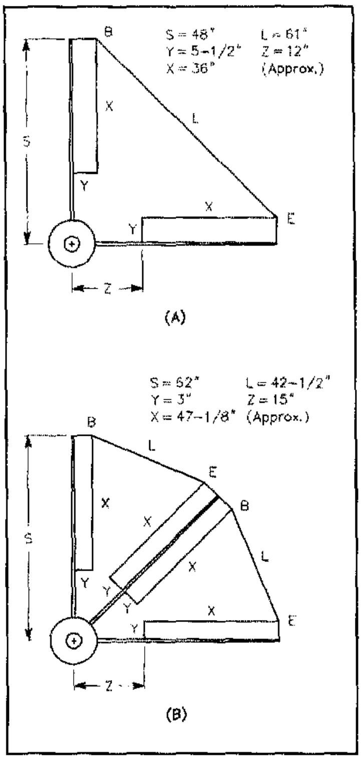

Figure 5—Dimensions of the various sections of the 12-meter Maltese Quad (A), and the 20-meter Maltese Double-Cross Quad (B). Points B and E are for wire attachment (see text).

quad element is shown in Figure 2. The inner drawing (that of the Maltese Double-Cross Quad) is of a wheel with eight spokes (eight spreaders). Its spreader diagonal, C-D, is only 10 feet 4 inches compared to the standard quad's diagonal (A-B) of 25 feet. A quite respectable difference!

Construction

Because of my former occupation, I have a junk box of materials that most hams do not, although the materials can be purchased. I also have a machine shop. Consequently, this isn't a step-by-step construction project with a detailed parts list. Nevertheless, the Maltese Quads have been duplicated by hams in other parts of the world. In fact, I know that a few have been built in England. These hams used tools and materials at their disposal, so put your ham ingenuity to work.[1,2]

Solid fiberglass fishing-rod blanks,[3] fiberglass tubing (or well-varnished bamboo, if you can find it) can be used for the spreaders. If you use fiberglass tubing, don't drill any holes along their length and thereby weaken them. Also, be sure to seal the tubing at both ends. The mechanical layout and the wiring of the reflector element is identical to that of the driven element, but the reflector is larger, as I'll explain later.

I'll refer to a single quad element as a "four-spoke wheel" (four spreaders) attached to a center hub (the spider). The rim of this four-spoke wheel is the wire perimeter.

The Linear-Loading Sections

Refer to Figures 3 through 5. Because linear loading is used (see Figure 3), the mechanical configuration of the Maltese Quad and its radiator wiring differ from that of the standard quad.

Clamped to the tip of each Maltese-Quad spreader is a short insulating arm (E-B), forming a T with the spreader. I refer to these short pieces as the "outer yardarms." About one foot from the hub end of each spreader is an "inner yardarm" (C-D). The inner and outer yardarms, and the wires running between them (E-D and B-C), form the linear-loading sections, with the inner conductive yardarm (C-D) being part of the radiating element.

Figure 3 shows how the lengths of the inner yardarms, C-D, and the outer yardarms, B-E, determines the spacing between the parallel wires, C-B and D-E. Changing this spacing alters the element's resonance. Changing the proximity of points C and D to the opposite points on the adjacent inner yardarm has the same effect.

The ends of the inner and outer yardarms have tie points to receive the perimeter wire and the wires of the loading sections. The dashed lines, A-F, indicate the course of the quad perimeter wire.

The outer yardarms on my quads are lengths of 3/16-inch-diameter solid fiberglass. At points B and E (Figure 3), the ends of the outer yardarms, stainless-steel, threaded, #8-32 studs receive the perimeter wire and the wires coming from the inner yardarms.

Each of the inner yardarms is a short length of 1/4-inch-diameter solid-aluminum rod equal in length to the outer yardarm. At points C and D, the inner yardarms have stainless-steel #6-32 machine screws, to which are attached the linear-loading wires coming from the outer yardarm.

Figure 3 shows a single spreader with its two yardarms in position. The lines A-F indicate the course of the Maltese Quad wiring perimeter. E-B is the fiberglass rod. C-D is the aluminum rod. The rod has an opening at its center to which a half-turn wire loop is temporarily attached. A dip-meter sensing coil is inserted into this loop during adjustment of the perimeter loop to the desired frequency. After the adjustment has been made, the opening is permanently shorted and becomes the attachment point for the gamma-match system. See Figure 4. (In actuality, the single spreader shown in Figures 3 and 4 assumes a vertical position—pointing down—in the finished quad.)

Don't attempt to use a single piece of wire for the perimeter wire and the wires in the linear-loading sections! Use one wire from B to C, and another from D to E. The wire identified as L between points E and B in Figures 5A and 5B should be a separate, single piece of wire.

Tune-Up

I used a dip meter in conjunction with a calibrated receiver to adjust each element to resonance. Whatever method you use, be sure to separately adjust each element to resonance. Then, assemble the driven and reflector elements on the boom. Once at-

[1]Notes appear on page 31.

tached to the boom, the individual element resonant frequencies will change because of their mutual interaction. This can be rectified once the antenna is matched to its feed line, and you'll be able to check the resonant frequency of the driven element as indicated by the lowest SWR point. You can then adjust the driven-element perimeter length—shorten it, or lengthen it—to raise or lower its resonant frequency. The reflector element perimeter can also be adjusted to increase forward gain, or front-to-back ratio, as you prefer. (I used this system in the frequency adjustments of all three Maltese Quads.)

When you get to the final perimeter adjustment, in order to achieve desired resonance (again, see Figure 3), move one inner yardarm away from, or toward, the hub center, removing or adding wire as required. I use the inner yardarm that is in line with the feed-point inner yardarm.

Figure 5A shows one quadrant of the Maltese Quad. The linear loading method for the 12-meter Maltese Quad requires about 17.5% more wire (7 feet) than a standard 12-meter quad. (I used 16-gauge [0.050-inch-diameter] copper wire.) The dimensions are those I used for the driven element of my 12-meter Maltese Quad, with a center frequency of 24.940 MHz. The perimeter of the driven element is 48 feet. The total perimeter for the driven element of a standard 12-meter quad is 40 feet 1 inch.

A standard 20-meter quad and a 20-meter Maltese Double-Cross Quad on 8-foot booms, using the diamond orientation, have turning radii of 13 feet and 6 feet 7 inches, respectively.

I mounted my Maltese Quad and Maltese Double-Cross Quad in the diamond position. This favors the height of the quad above ground, and there is less tendency for ice build-up on the wire perimeter. In addition, this orientation provides an ideal site for the feed point and its associated matching network.

Going Down?

I've concluded that a Maltese Double-Cross Quad for 40 meters is feasible—and a tempting project! A standard 40-meter-quad element requires a spreader diagonal of about 49 feet, whereas a Maltese Double-Cross Quad needs a spreader diagonal of *only 19 feet!*

Going Up?

Applying the Maltese Quad linear-loading system for 2, 6, and 10-meter quads—using aluminum tubing rather than copper wire for the radiator—would provide a self-supporting, rigid quad frame. You'd need a plastic hub (spider), but no spreaders would be required (see Figure 6).

Empirical Conclusions

Not having access to an antenna range, the conclusions regarding the performance of a Maltese Quad versus that of a standard quad have been made through on-the-air contacts. One of the most valuable series of these tests was that with Joseph J. Belson, K2ANR, of Riverhead, Long Island, New York, whose location is some 60 miles from mine. Through the years, both of us have realized the importance of a superior antenna system, and we both "graduated" (changed our direction of antenna experimenting from Yagis to quads) at the same time, except that Joe uses a standard quad.

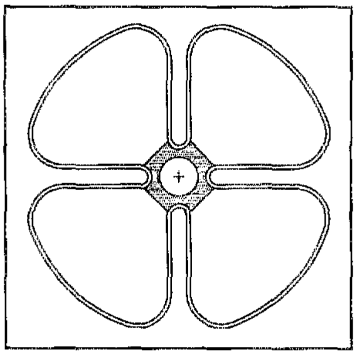

Figure 6—Front view of a quad element for the 2, 6, or 10-meter bands applying the Maltese Quad linear-loading system. Rather than copper wire, aluminum tubing is used for each radiator in conjunction with a plastic hub (spider). This would provide a self-supporting, rigid quad frame without the need for spreaders.

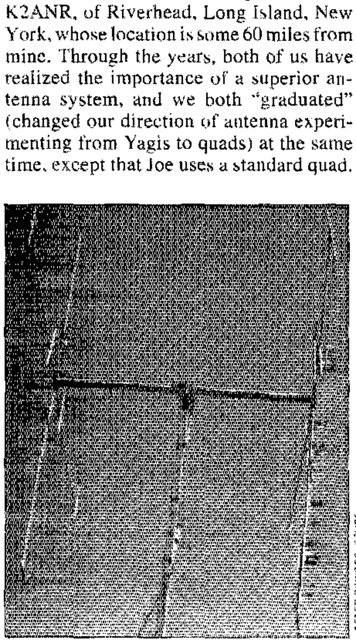

Figure 7—Peter (GØHES) Bowers' version of the Andy (K1KLO) Pfeiffer compact linearly loaded Maltese Quad for the 12-meter band. The spreaders are solid 10-mm fiberglass rod, as are the outer yardarms. The inner yardarms are 10-mm aluminum tubing. High-density plastic forms the hub and the boom is made of 44-mm-OD fiberglass tube. For the perimeter wire, 1.25-mm-diameter enameled copper is used.

Over a two-year period, Joe and I conducted many three-way QSO comparison tests on the 12- and 17-meter bands under all conditions covering all continents. We've concluded that the two quads perform equally. That is, front-to-back ratio, forward gain and side rejection are the same. (Joe's quads are a good deal higher than mine, but the height difference didn't seem to matter. The lowest point of my quads is about one-half wavelength or less above ground. Joe and I both ran about 100 W during these experiments.

My 2-element, 20-meter monoband Maltese Double-Cross Quad on an 8-foot boom has been in service since March 1993. It's made a good account of itself, signal reports being consistent with those received from the 12- and 17-meter Maltese Quads on their respective bands.

It's a real pleasure for one person to be able to assemble a 2-element 20-meter quad, attach its boom and mast, and then easily carry the complete assembly to its location!

I use a gamma match on all my quads; I feel comfortable with this system. The 2:1-SWR bandwidth of the 12- and 17-meter Maltese Quads is in excess of 500 kHz. The 20-meter Maltese Double-Cross Quad presents no problem to my TS-180S on frequencies from 14.0 to 14.350 MHz.

After hundreds of contacts with the Maltese Quads, I can say without hesitation that my system has not degraded the bandwidth or the other favorable characteristics of the standard quad. The standard quad is a very low-Q antenna—most forgiving; the Maltese has not altered these important qualities.

An Acknowledgment

As with my past antenna experiments, I'd not have been able to see this project through to its conclusion without the invaluable aid of my wife, Marianne, who through the years has weathered the brainstorms of K1KLO.

Experimentation

For those of you who'd like to experiment with the linear-loaded quad configuration, here are some notes, hints and thoughts.

In determining the dimensions for a 2-element monoband quad, I used the formulas found in Bill Orr's cubical quad handbook.*

Total driven element perimeter:
$1000 \div f_{MHz}$ (Eq 1)

Total reflector element perimeter:
$1032 \div f_{MHz}$ (Eq 2)

Element spacing: $118 \div f_{MHz}$. (Eq 3)

I've not developed formulas that determine the relationship between the driven and reflector elements for the Maltese Quads. Therefore, I translate the length of one side of the standard reflector element to the frequency

*W. Orr, *All About Cubical Quad Antennas* (Wilton, CT: Radio Publications Inc, 1971), 2nd edition, 2nd printing.

that this length establishes. For example, in selecting a frequency of 14.2 MHz for a standard 20-meter quad, one side of the reflector is equal to 18.169 feet. This dimension, applied to the formula 250 ÷ 18.169 feet, results in a frequency of 13.759 MHz. I then adjust the reflector element to that frequency.

During my first experiments for this project, I used an element with four 8-foot-long spreaders. The four inner yardarms were fixed 12 inches from the hub center. The four outer yardarms were adjustable at 6-inch intervals from the spreader tips down to 3 feet from the hub center. Then I wired up the element perimeter with the outer yardarms set at the 8-foot locations and measured and recorded the element's resonant frequency. Next, I moved the four outer yardarms 6 inches toward the hub center and rewired the element. I checked this new element's resonance and recorded it, repeating the process down to the 3-foot marks. This data is valuable in planning Maltese Quads for other bands.

I applied this same testing technique in experiments with the Maltese Double-Cross Quad, with the following two changes: The eight inner yardarms were fixed at 15 inches from the hub center, and all yardarms, inner and outer, were reduced in length to 6 inches (see Figure 4B).

When conducting Maltese Quad experiments, be aware that the diameter of the perimeter wire used for the finished quad *must be the same as that used in the experimental antenna.* For example, if you use 20-gauge wire (0.032-inch diameter) in your experiments, and use 14-gauge wire (0.064-inch diameter) in your finished quad (using the same total length of wire), you'll find that the finished element's resonant frequency is about 1 MHz higher.

Notes

[1]For some additional information on standard quad construction, see W. Stein, "A Five-Band, Two-Element Quad for 20 through 10 Meters," *QST*, Apr 1992, pp 52-56; K. Wellenius and Björn Wellenius, "A Light and Sturdy Quad for 10 and 15 Meters," *QST*, Jul 1993, pp 30-32, and *The Radio Amateur's Handbook*.

[2]I recently had the distinct pleasure of working Maltese Quad to Maltese Quad! *That* was an experience I'll never forget! Peter Bowers, GØHES, was kind enough to send me photos of his version of the Maltese quad. (See Figure 7.)

[3]Fiberglass rod, tubing and square-sided tubing is available from Max-Gain Systems Inc, 221 Green Crest Ct, Marietta, GA 30068, tel 404-973-6251. Solid and tubular fiberglass fishing-rod blanks are available from: Netcraft Co, 2800 Tremainsville Rd, Toledo, OH 43613; for orders, tel 800-638-7238; customer service, 419-472-9826.

Until his retirement in 1986, Andrew (Andy) Pfeifler, K1KLO, was a self-employed medical research instrumentation consultant in the field of neurophysiological studies. Through the years, his consuming interests in Amateur Radio have been antenna experimentation, design and construction. A few of his other interests are hiking in New Hampshire's White Mountains with his wife, Marianne, and amateur archeology and archery. Andy is unable to answer written inquiries, but can be reached by phone at 203-434-5621.

New Books

THE BEGINNER'S HANDBOOK OF AMATEUR RADIO

By Clay Laster, W5ZPV

TAB Books, McGraw-Hill Inc, Blue Ridge Summit, PA 17294-0850; tel 717-794-2191, fax 717-794-2103. Third edition, March 1994. Paperback, 416 pp, 210 illus, 7×10 inches, retail price $21.95, ISBN 0-8306-4354-0.

Reviewed By Brian Battles, WS1O
QST *Features Editor*

It's a nonham's introduction to Amateur Radio! It's a license manual! No, it's both! Well, actually, it's not quite either.

It can be frustrating for a seasoned ham to try to entice someone else to join him or her in the hobby because the reasons for wanting to be a ham are notoriously intangible. What a job it is to make Amateur Radio clear and enticing to an outsider. Telling someone how much fun it is to make two-way radio contacts with random strangers can make Amateur Radio appear downright pointless or frivolous to nonhams. In a one-on-one, face-to-face conversation, this can be difficult; in print it's an enormous challenge at best. (So far, the only book I've ever read that pulls this task off well is *Ham Radio Horizons: The Book* by Peter O'Dell, WB2D; see New Books, November 1993 *QST*, page 49).

You're not going to buy a copy of this book for Aunt Flo to transform her from someone who thinks there's lightning inside the wall sockets to a devoted ham radio enthusiast. This isn't an invitation to the hobby for nonhams, it's not positioned as a license manual and it's not a comprehensive reference to electronic communication like *The ARRL Handbook*. Many experienced hams can't imagine how little the average person knows about basic electricity, let alone radio electronics, and it takes a deft touch to introduce it without frightening a beginner with complicated lessons and details. Because there are excellent texts available that focus on license exam preparation, it can be argued that another one isn't necessary.

Having stated what this book *isn't*, can we determine what it *is*? This is where it's confusing; Laster's book is a bit advanced to be an introduction to Amateur Radio for people who know little about the hobby. On the other hand, it's sort of a preparation manual for the entry level FCC licenses. When Laster explains what ham radio is, he does a good job of making it sound like a fun and intriguing pastime. Instead of concentrating on that theme, however, he segues right into FCC Rules, basic electronics theory, equipment and antenna topics, and operating details beyond the typical needs of the person who's a true beginner in Amateur Radio. In some ways, the technical information he discusses isn't quite complete enough to recommend this as an in-depth license-preparation manual, and in some areas it takes you considerably beyond the material covered in the exam question pools. Laster goes a few steps toward serving as an Elmer who can "clue in a new guy," and he often refers to the ARRL and what it has to offer new and potential hams—in several places he recommends that readers take advantage of League information, resources and services.

So what *is* the *Beginner's Handbook of Amateur Radio*? I'm not sure, and I don't think Laster is, either. It appears that what may have begun as a means to express his enthusiasm for explaining everything to newcomers went beyond the scope of what a prospective or beginning ham may want to read about—in fact, it's not hard to imagine a reader starting out with a sense of excitement, but becoming slowly turned off by the technical material. It's not poorly written, there are plenty of interesting and useful photographs and illustrations, and some worthwhile tutorial and reference material for hams, but it needs a slightly tighter focus. As it stands, it seems best suited as a nice supplemental resource for someone who's studying for a ticket or has just received a new license. Perhaps retitling it *The Beginning Ham's Handbook of Amateur Radio* would be a step in the right direction.

ENCYCLOPEDIA OF ELECTRONIC CIRCUITS, VOL 4

By Rudolf F. Graf and William Sheets

TAB Books, McGraw-Hill Inc, Blue Ridge Summit, PA 17294-0850; tel 717-794-2191, fax 717-794-2103. First edition, first printing, 1992. 650 pp, B&W schematic diagrams, 9¼×7¼ inches. Retail $29.95. ISBN 0-8306-3895-4.

Reviewed By Bruce Hale, KB1MW/7
2238 168th Ave NE
Bellevue, WA 98008

The Encyclopedia of Electronic Circuits is a hefty 650-page collection of circuits pulled from a variety of electronics magazines, including *QST*, *73 Amateur Radio Today*, *Popular Electronics* and *Elektor Electronics*. Each circuit is presented with only a brief description and average one circuit per printed page—as many as three circuits are presented on some pages; other circuits require two pages.

The circuits are an interesting collection, ranging from audio mixers through power supplies and battery chargers to FM wireless microphones and model-train controllers. Some are simple and easy to build, while others are practically impossible without referencing the original article (some descriptive text is missing or the parts are difficult to find).

Graf and Sheets could have been more selective in choosing circuits. I haven't seen volumes 1-3—perhaps the well has run a bit dry and those volumes are more useful. I did find some interesting circuits—I built a NiCd battery charger and there are a few other circuits I'd like to try. But at $29.95, I can't recommend that you buy this book without taking a good look at it first.