Ralph W. Campbell W4KAE
405 Granite Circle
Lexington KY 40503

TOROIDAL QUADRATURE ANTENNA

My work on the "Long Circular Quad," was a needed departure into endfire antenna design which proved ring shaped elements to be superior to discrete directors in – the possibly obsolete – Yagi configuration. Extensive tests on a professional antenna range proved that.

Another, although unproved departure from the norm, was George A. H. Bonadio's *Square / Diagonal Antenna*, commonly thought to be a diversity antenna, when in reality it is quite similar to an '8JK multi-driven element collinear/broadside array.

While these two antennas have nothing in similarity except their novelty, however, it might interest the reader to know that W4KAE spent many hours contemplating just the same arrangement that Mr. Bonadio thought up, except he couldn't stand the idea of using tuned lines – so the project was abandoned. I guess what I had in mind was a point-source with gain. Anyway, after reading W2WLR's article, I knew the principle of operation: Simply use 90 degree physical and electrical phasing on each pair of 4 or 8 wires; place them in the correct plane for the desired radiation; and even semivertical "diversity operation," can be obtained. True diversity would require more than one set of antennas – not simply relays!

These random thoughts and conclusions led W4KAE to test the "Quadrature Approach" in practical form, without tuned lines or relays. Being familiar with the quadrature phasing (90°) concept for winding low-power octave bandwidth receiving networks, I immediately began to wind the coils for the "Toroidal Quadrature Antenna."

TQA Theory

Reiterating the phasing concept above: The Square/Diagonal Antenna is basically no more than a set of four wires, arranged in phase quadrature. This means there is ninety electrical degrees between each leg, and preferably 90° physical/angular "spacing" between each wire. The length of the elements can be made from either one or two *electrical* wavelengths, the choice depending mostly upon space and gain desired. Optimum design standpoint would utilize a minimum physical wavelength of about 3/8 wavelengths-per-leg. This is doubled to be 3/4 wavelength because of criss-crossed quadrature connections to the transforming coils – and the whole element functions as a full electrical wavelength – with the additional "length" contained in the coils. Obviously whenever a particular design is op-

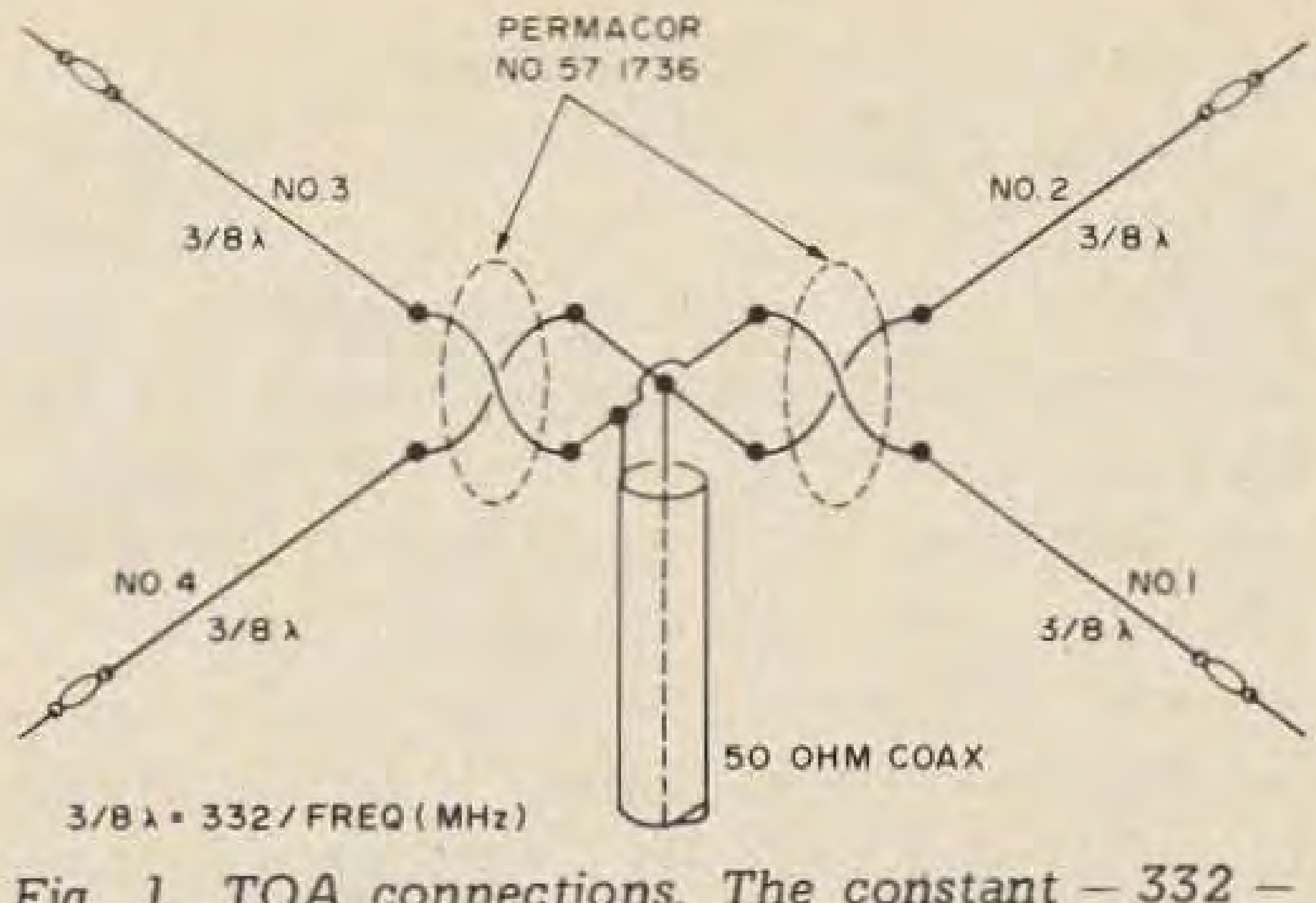

Fig. 1. TQA connections. The constant – 332 – includes shortening factors and quad-coil loading.

timized by cut-and-try coil wind and substitution, lowest swr readings are the criterion of proper operation, along with proper continuity tests.

Derivation of element formulas is quite simple – if you don't overlook the ninety degrees in the network! Keep in mind also that since each complementary two-wire element functions as one full wavelength, you must double the usual shortening factor. There is also 2 or 3 per cent compensation present using 10% instead of 5%. We won't go into that, however.

Figure 1 shows the quadrature networks in use by W4KAE. Briefly, to calculate an element length (equal to two "legs") we take 984 minus 246, which leaves a new constant of 738. From this figure, ten per cent is to be taken off, or about 74 from 738, which leaves 664. $664/F_{MHz}$, is for 3/4 physical wavelength. Half of this is $332F_{MHz}$, for each 3/8 wavelength leg. This arithmetic is for the optimum or small-space model. If you want two to four decibels (estimated) additional gain, use the following method:

Take twice 984, or 1968. Take twice 74 or 148 off, for double the 10% shortening factor. Next, take off twice 246 from the number 1968, which leaves 1476. From 1476 subtract the shortening factor (148) found above. This leaves the figure 1328 or $1328/F_{MHz}$ which is for two legs. Half of this becomes $664/F_{MHz}$ which is exactly double the 3/8 wavelength previously. It is also a good check. I have no information about swr in this design.

The TQA connections are made in Fig. 1. Observe that there is dc continuity between elements No. 1,3 and No. 2,4. Similarity to the W2WLR design can be seen where the classical 90 degree phasing, from element to element, is obvious. Dashed-line ellipses are representative of the powdered iron Carbonyl SF cores.

Gain obtained from the TQA should be about the same as from W8JK's two-section flat-top, which appears on page 151 of *The ARRL Antenna Book*, ninth edition, 1960. The spacing between each bay of endfire elements is conveniently eliminated in our version of the Toroidal Quadrature Antenna. Noting the continuity between complementary legs, it is only a short step to place each wire at physical right angles with the other, for overall correct phasor relationships. String the whole array into the same vertical or horizontal plane and you've got an improved quadrature design. With two arrays, in opposing planes, then you have true diversity, not just semi-vertical polarization! Here, a relay and switching networks would be feasible.

Although I do not have facilities to accurately check actual gain readings against a dipole, it should be adequate to figure, by rule of thumb, that 6 dBD is available for the "optimum" design; or 8 dBD for the longer model. Maybe you could expect 10 dBD by combining both collinear and broad-

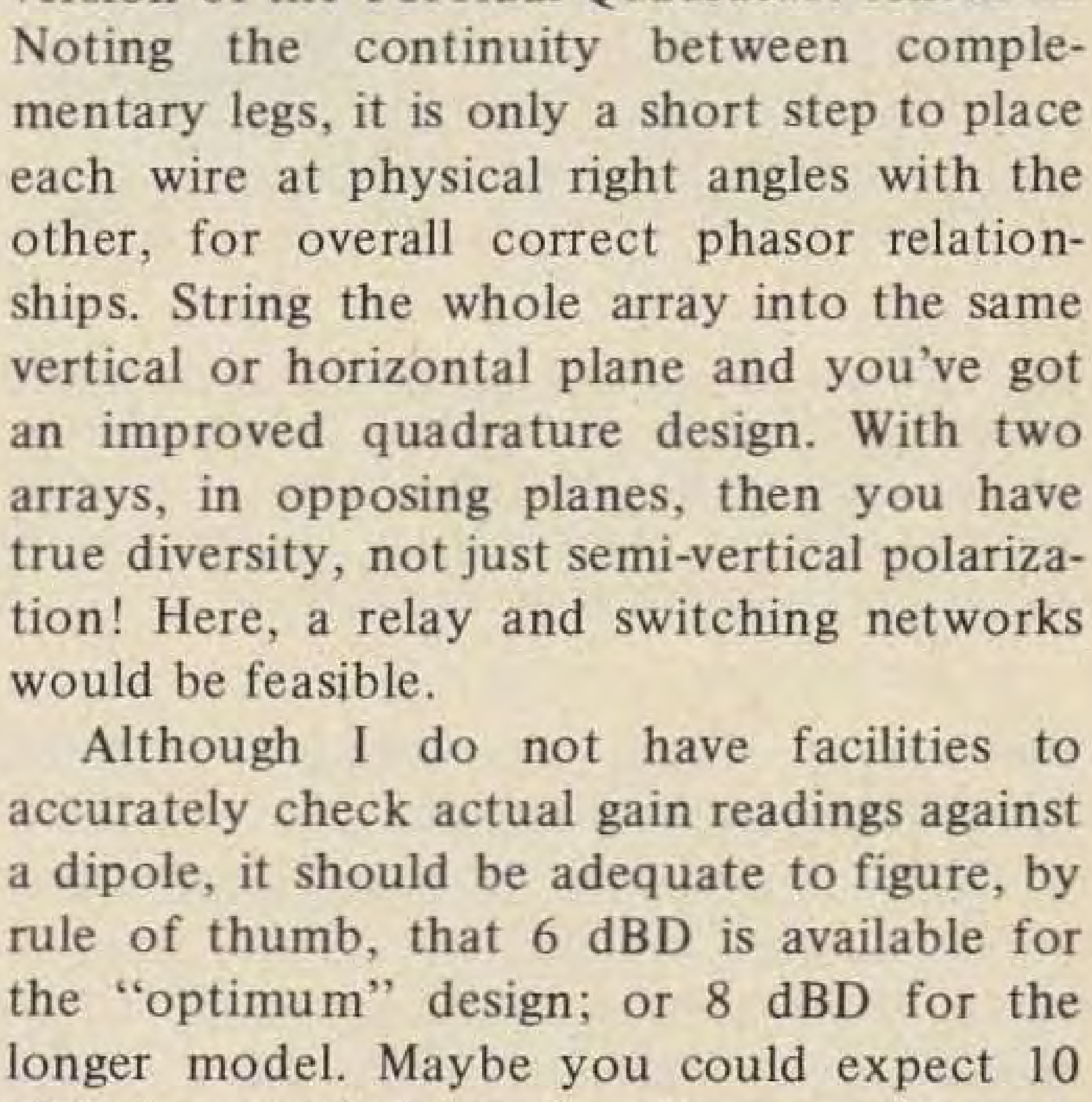

Fig. 2. TQA receiving coils. With wire of proper size and leg length of about 15 ft, reception for SWL and WWV monitoring is satisfactory. Frequency coverage from an octave below the normalized frequency to an octave above, is feasible.

Fig. 3. This shows the quadrature coils before encapsulation. Two No. 57-1736 Permacor cores are wound with No. 16 Beldsol wire, in a bifilar fashion. This pair is for 6 meter sample, sent to Wayne Green for testing on that band.

side arrays. These conclusions are based upon the reference cited above.

Figure 2(normally I'd have included this photo in the construction section, but it exemplifies proper winding data, here) shows my first torodial coils. This was for general coverage use, with reception coming in on virtually all high frequency bands, and particularly, WWV. My design used No. 24 wire, wound fully in bifilar manner on the toroid cores. This is a 1:1 design ratio.

It was a rainy day when this shot was taken, so it is hard to see the input port cable connection in the middle-left with a cut piece of RG-58/U soldered on. The wire connections have been bared to show cores and the aluminum ground wire connections. The aluminum was swaged and wrapped to the smaller wire ends and held together with a plastic rod, through the cores, and the whole works doused in clear epoxy resin. This receiving design resulted in antenna resonance at 11 MHz; however there was excellent pickup an octave higher at 22 MHz and beyond. Lower-octave reception down to 5.5 MHz was quite good! To the nearest amateur band: 15 meters is recommended, while *reception* of WWV at 10 MHz should be "optimum."

Practical Antenna Construction

Figure 3 shows an improved 50 MHz set of quadrature coils. Note that they are similar to a five port circulator, having four output ports in common with earth ground, back to the antenna structure, when connected. The input port doesn't share the same phase of any of the output ports with ground, so there is reasonably good balance without an external balun. It can be shown that the balancing action from the worst two on any pair of wires is +90/Ground Isolated/ -90 basis. You can see the total phase difference is still 180 degrees, but the coaxial cable "ground" is not the same as earth ground.

Figure 4 shows an improved 50 MHz array, as strung up in W4KAE's attic. The elements are mounted in a vertical plane but the reception or transmission is horizontal, as would be expected. This antenna was loaded by my TX-62 on 6 meters giving an swr of 1.5 to 1, in the basement laboratory. By making it "droop" like the drooping ground plane (not illustrated) the swr went down to 1.3 to 1.0. A drooping TQA hanging from a set of square supports should

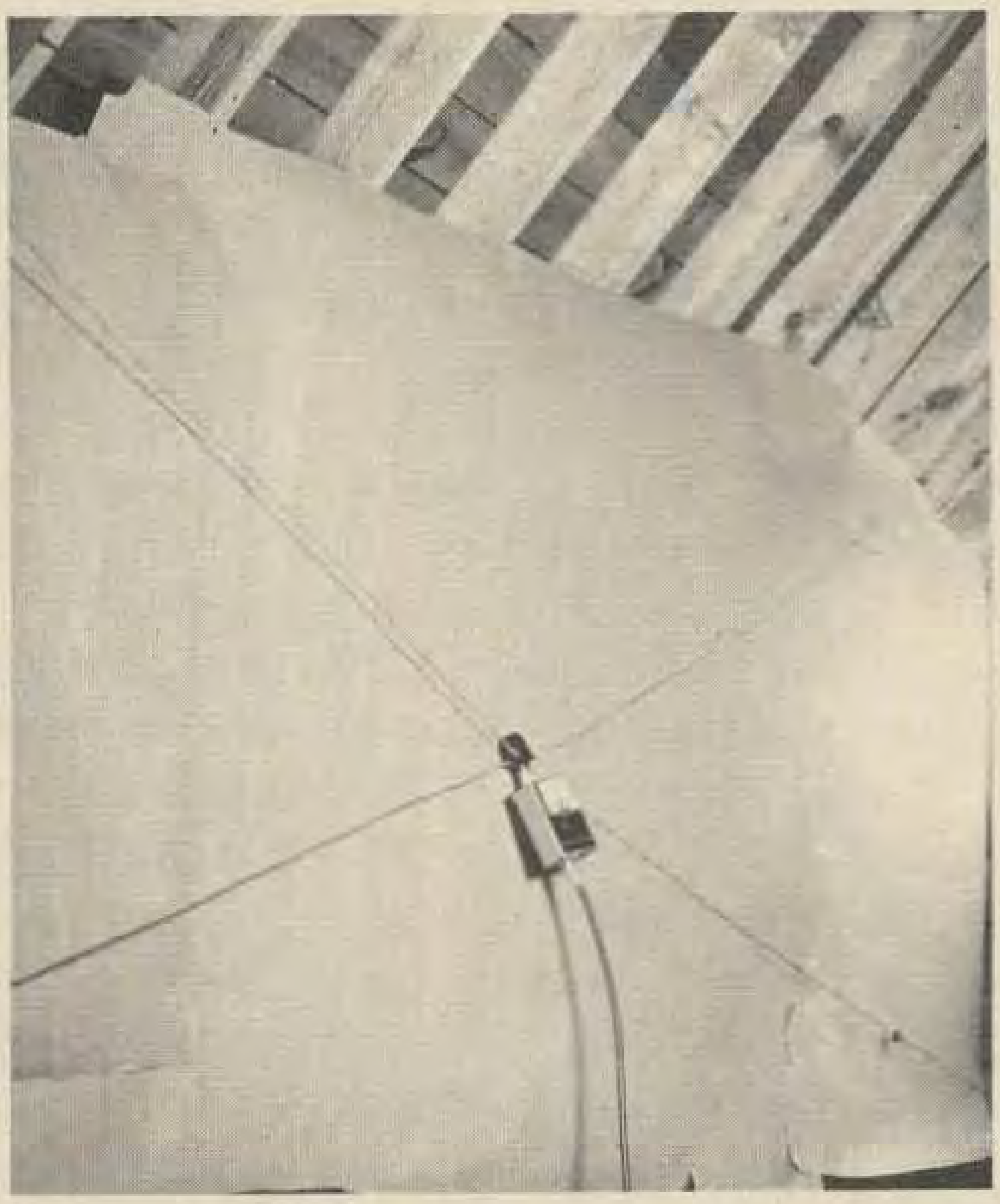

Fig. 4. The completed 6 meter Toroidal Quadrature Antenna. Individual leg lengths re about 6 2/3 ft. Swr about 2 to 1 with legs not equally angular spaced. (When first tested in my basement lab: swr was only 1.5 to 1. Drooping will improve readings.)

out-perform a "Halo, Squalo, or even Big Wheels," on VHF.

Figure 5 shows the TQA in packaged form ready to be sent to the editorial research department of *73* Magazine! The toroidal coils are heavily potted in silicon rubber, with an overcoating layer of Valspar No. 8880 glass plastic resin. (This clear resin is no good when in intimate contact with coils, toroid cores or any dielectric use.) In the Valspar resin flat 1/8 in. copper strap is secured, after being soldered. Then the molded network was taped to help secure mechanical strength. Prior to taping, the copper strap was silver-soldered to silver-plate No. 10 ground wire.

Toroidal Core Materials

The toroidal phasing coils are made with Permacor Material No. 12, Carbonyl SF powdered iron mouldings. The stock number is 57-1736. They are available from *Permacor Division of Radio Cores, 9540 S. Tulley Ave., Oak Lawn, Illinois,* on a $10.00 minimum order basis. It may be possible to get several samples free, by writing on your company letterhead.

With the No. 57-1736, six meter networks can be made by winding bifilar two lengths of No. 16 enamel wire (Formvar preferred), covering all the core space possible. For 10 to 20 MHz, a full bifilar winding of No. 24 enamelled wire is permissible, but the coils will only take 100W PEP or so. For 160 meters and/or 80 meters, Permacor No. 57-1516 is a good choice since it is considerably larger.

If good VHF/UHF networks are desired I must recommend ferrite – not powdered iron – cores. Indiana General makes a very high quality core, size CF-111-Q_3 which is almost identical in size to the Permacor 57-1736. I do not know where these can be obtained. In the meantime X-7541 cores are in use at W4KAE (Permacor Iron-9) – but I am anxious to try the Q_3 material. For two meters, with the CF-111 size ferrites, wire size should be No. 14.

Conclusion

At the outset I mentioned the LCQ in opening remarks about the TQA. This is because they are both new departures in contemporary antenna design. The LCQ: A Yagi replacement at least for UHF; and the TQA is a 40 or 80 meter quad or rotary beam replacement. It can also be used on 160 – if you have the room.

Fig. 5. The TQA is ready to be shipped. The entire antenna and insulators are easily contained in an old shoe box. With aluminum ground wire elements, the weight was very little.

It is my opinion that the cubical quad antenna, as already perfected, is ideal for use on 10, 15 and 20 meters – also for 6 or 2 unless you want broad angular coverage. Then the TBA is still practical when wound with good ferrite cores. DXing on 6 meters is still best accomplished using 11 element Yagi designs, I hear; however I'll be glad to recommend my LCQ to home-brewers.

Although the 6 meter design is featured in this article, it is primarily an HF antenna replacement for rotaries when used N/S or E/W in array. With two medium height aluminum masts we can string up a wire element replacement for the Inverted Vee – or – it can be used as a 4 wire Vee that is completely omnidirectional, with only a single set of coils! It will also work on at least one octave of frequencies, on a reciprocal basis, or two octaves in the receiving mode. ...W4KAE