Rebuilding the 80-Meter Four-Square at N6RO

Gary Johnson, NA6O July 2017

For many years, the four-square antenna has been a top performer on 80 m at N6RO. It's age was showing so we decided to rebuild it using better sub-assemblies and a bit of modeling to optimize it for updated SSB and CW center frequencies. It uses wire vertical elements supported by catenaries off of a central tower. At each corner is a feedpoint box at 10 ft elevation. Each vertical has a pair of elevated radials, installed as high as we can. A switchable matching coil for the CW portion of the band is placed in series with the radials (shorted by a relay for SSB). The control box is the popular Comtek ACB-4-A.

The first thing I did was to take careful measurement of each wire, and also check the resonant frequency of each corner. From this data, I was able to estimate updated radial lengths, see if the verticals were equal length (they weren't), and verify that the square was truly square (it wasn't).

An EZNEC model was constructed that included the feedline/phasing line, the CW matching coil, and a common-mode choke at the antenna base. A great deal of information was gleaned from this model in addition to basic wire lengths and feedpoint impedance. First, we can find a good working value for the matching coil and kHz of tuning per turn of the coil. Second, we get the tuning rate when trimming radials (about 20 kHz per foot). Third, I was able to study the performance of the choke and its potential power dissipation.

What happens when there is no choke? The feedlines look much like another radial, though mistuned with a different length. The model indicates that coax shield current could be about 20% of that in a radial, or 300 mA with 400 W applied. This will not only affect tuning, but also invites electrical cross-coupling between the four antennas since they share a common power source. Adding a choke impedance of 6000 ohms reduces the current to <10 mA.

Four-squares present a challenge for choke design because of phasing line length. You need exactly 90 degrees of electrical length at a desired center frequency (here, 3650 kHz). You can't just add an arbitrary bunch of cable wrapped around a stack of toroids; if you use too much cable in the choke, the feedline won't reach the control box at array center! After a discussion with Jim, K9YC, I did some experiments and settled on a stack of two 2.4-inch type 31 toroids wound with 10 bifilar turns of #10 AWG magnet wire. The line impedance was very close to the desired 75 ohms (phasing lines are RG11). About 3.5 feet of wire was required, leaving sufficient coax length. Most importantly, the common-mode impedance was around 6000 ohms, and 80 m was very close to the self-resonance peak, so it was nearly all resistive (Fig. 1). By the way, winding stiff #10 wire around that choke was about all I could handle; it raised a few blisters.

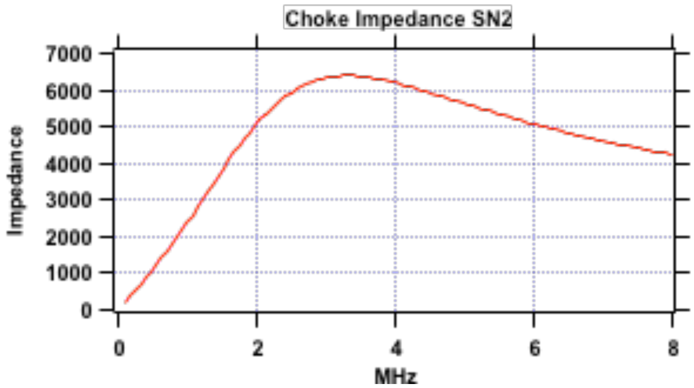

Figure 1. Common-mode impedance of the choke was pleasingly high and almost purely resistive in the 80-meter band.

An often-ignored concern with any common-mode choke is power dissipation. A highly-unbalanced antenna run at high power is a recipe for the *Flaming Balun* award. Fortunately, the vertical antennas in this application are fairly well balanced. EZNEC showed that under the expect range of operating frequencies and powers, less than 1 W would be dissipated. With unequal radials (off by 2 ft), it increases to 1.5 W. Only with a very short vertical element or a damaged antenna does dissipation become excessive.

Just to be sure, I did a temperature test on an actual choke. I wrapped it with a long length of #28 magnet wire to serve as a heating element, placed it inside a closed container, and measured temperature rise. With 5 W continuous (Fig. 2), I would say there is little danger of destruction nor of reaching the curie point, 130 degC. Another test was run at a rather extreme 30 W (Fig. 3). This was headed for trouble, reaching 70 degC in 13 minutes before I uncovered it, after which it seemed to settle at 65 degC. So here we have some practical data. My final decision was to add vents to the enclosure, considering the fact that the matching coil and relay coil also dissipate a few watts.

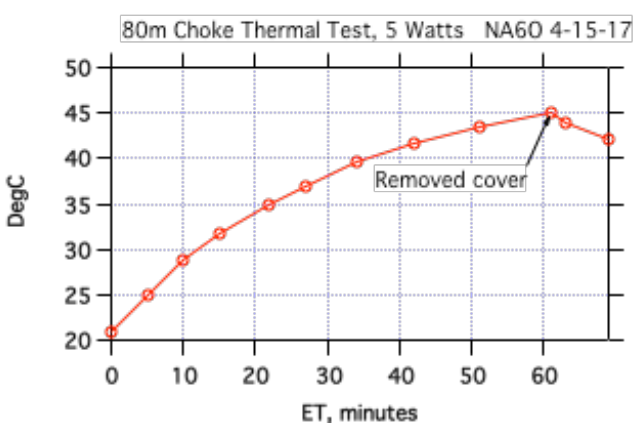

Figure 2. Choke temperature rise with 5 W dissipation. Looks safe enough.

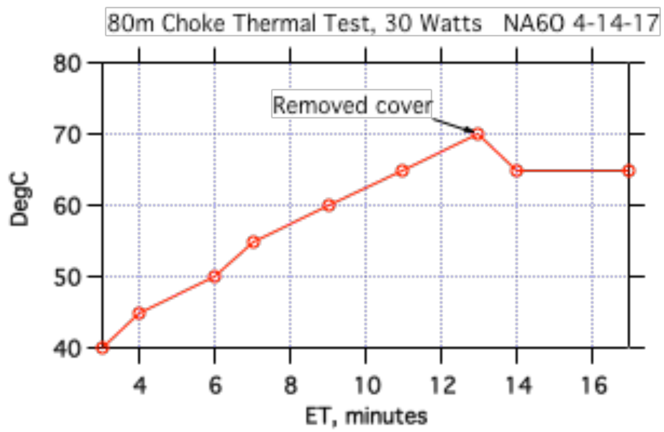

Figure 3. Choke temperature rise with 30 W dissipation. This could be trouble...

Components were assembled into a very rugged 6x6x4 inch plastic electrical enclosure, using all stainless and brass hardware (Fig. 4). A static bleed resistor was added across the antenna. Yes, the SO-239 is genuine Amphenol. All components were high-pot tested to 1.4 kV.

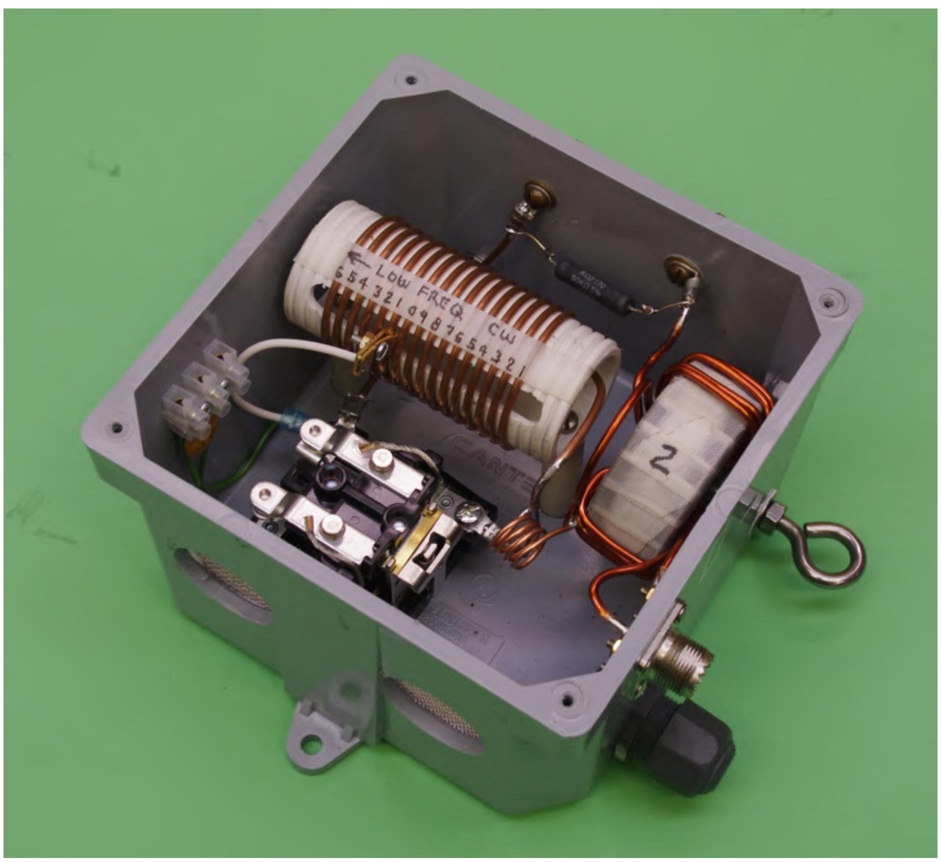

Figure 4. One of the four enclosures. This is what we call CONTEST-READY hardware.

The next step was to fabricate matched phasing lines from RG11. Since the objective is a 90-degree phase shift including the cable, choke, and everything else in the box, that is the configuration I tested end-to-end. By measuring all of that on my N2PK VNA in transmission mode, each set was matched within 0.1 degree at 3650 kHz. That should be good enough! The good news about making my own phasing lines is that I was able to install Kellem grips at each end to that the cables would not sustain damage when suspended (Fig. 4).

Another run of wire is required to supply 12 VDC to the relay. For this I used 2-conductor direct-burial sprinkler cable. This stuff is cheap ($108 for 1000 ft on Ebay, $150 at Home Depot), and its polyethylene jacket will last forever. You can get it with up to 10 conductors (#18 solid). Highly recommended.

Figure 4. Antenna box installed. Feedlines have nice strain reliefs. This should hold up well. If only the wires would survive all that flexing the wind.

At last it was installation time. I am most grateful to Lee, KI6OY, for helping me out in the sun and wind. It took us about 15 hours over two days to complete the project with about half the time spent repairing and adjusting radial lengths. Based on measurements on the previous array, we knew that the individual verticals needed to resonate 50 kHz below the combined array frequency, and that turned out to be right on. Heading to the shack for the smoke test, array resonance for SSB and CW was exactly as predicted and no further adjustments were required. Bandwidth, based on 10% dump power, was almost 300 kHz for each band setting. I believe the reason that it tuned so well was that I used the antenna terminals (the wire ends) as the reference plane for phasing line matching, antenna tuning, and all the modeling work. Ken will be giving it a workout in coming weeks along with an evaluation of directivity. This installation should have a long service life, give or take a few wires that break in the wind.

Figure 5. One corner needed its position adjusted, and a new 4x4 support. Here, Gary earns his PhD (Post Hole Digger).

Figure 6. Lee KI6OY tends to the Comtex box. SO-239s get a coat of Dow DC4 dielectric grease, and a good tightening.