

The N4GG Array

Need a simple, nearly invisible wire antenna with reasonable gain, low-angle radiation (for DXing) and multiband capabilities? Check out this long-overlooked design that requires no antenna tuner.

Having been relegated to a “no antennas,” deed-restricted neighborhood five years ago, I started a search that’s unfortunately becoming more and more familiar to hams everywhere. It’s the search for a stealthy multiband antenna that has decent DXing performance. Wire antennas seem right for invisibility, but on-air testing of dipoles mounted close to the ground confirmed what seasoned hams and antenna modeling packages will tell you: A dipole mounted less than $\frac{1}{4}$ -wavelength above ground is essentially radiating straight up! The earth makes an effective, if lossy, reflector, and the emitted RF does a great job of warming the clouds. Low dipoles and inverted Vs are fine for local contacts, but are relatively poor performers for long-haul DX.

Searching through various antenna handbooks led me to consider verticals and a variety of vertical arrays, but the radial field usually required for efficient operation can’t be practically implemented in my suburban setting. And even under the best of circumstances it’s a major project. Ever try putting 60 radials for 80 meters on top of, or under, a grass lawn without your neighbors asking you what you’re doing? Even the placement of ground-mounted verticals at my location was problematic. The vertical(s) would have to be inside a dense stand of trees or very near the house. Traditional verticals were out.

Self-contained verticals looked promising. These include delta loops and quad loops, among others. They yield low-angle radiation and do not require radials. They’re also large and hard to operate on multiple bands without an antenna tuner. Closed loops cut for different bands often can’t be fed in parallel. Most multiband approaches include some combination of relay switching, multiple feed lines, matching networks and antenna tuners. Did I forget to mention that in addition to gain, low-angle radiation and stealth, I wanted this antenna to be simple? Also, because I don’t own a high-power antenna tuner, I wanted a reasonable SWR at the operating

frequencies of interest.

Among the self-contained verticals is the *half square*, which looked like a nearly ideal approach except, again, for the difficulty in erecting a version that works on multiple bands without a tuner. The bobtail curtain also had possibilities, but it’s usually shown fed at ground level against radials and is not inherently multiband in nature. It was time to fire up *EZNEC* and see if some new variation of a self-contained vertical could be devised. A few hours later the N4GG Array debuted—at least on paper!

Design Details

Technically, an N4GG Array consists of two top-fed, $\frac{1}{4}$ -wavelength verticals spaced 1 wavelength apart, fed 180 degrees out of phase. Think of the array as a bob-

tail curtain with its center wire replaced by the feed line. Bobtails aren’t particularly well-known, so if the bobtail analogy is hard to grasp, think of the N4GG Array as a $\frac{3}{2}$ -wavelength horizontal dipole with the last $\frac{1}{4}$ wavelength of wire on each dipole leg bent at 90 degrees (hanging vertically). Figure 1 shows a bobtail antenna (A) and the single-band version of the N4GG Array (B).

Not too familiar with a $\frac{3}{2}$ -wavelength dipole? If you’ve ever used a 40-meter dipole on 15 meters, you were using a $\frac{3}{2}$ -wavelength dipole. Figure 1B shows the current distribution along the wires. Note that maximum current (and therefore maximum RF radiation) is at the top of the antenna. The antenna is center-fed with coax and should include a 1:1 current-type balun.

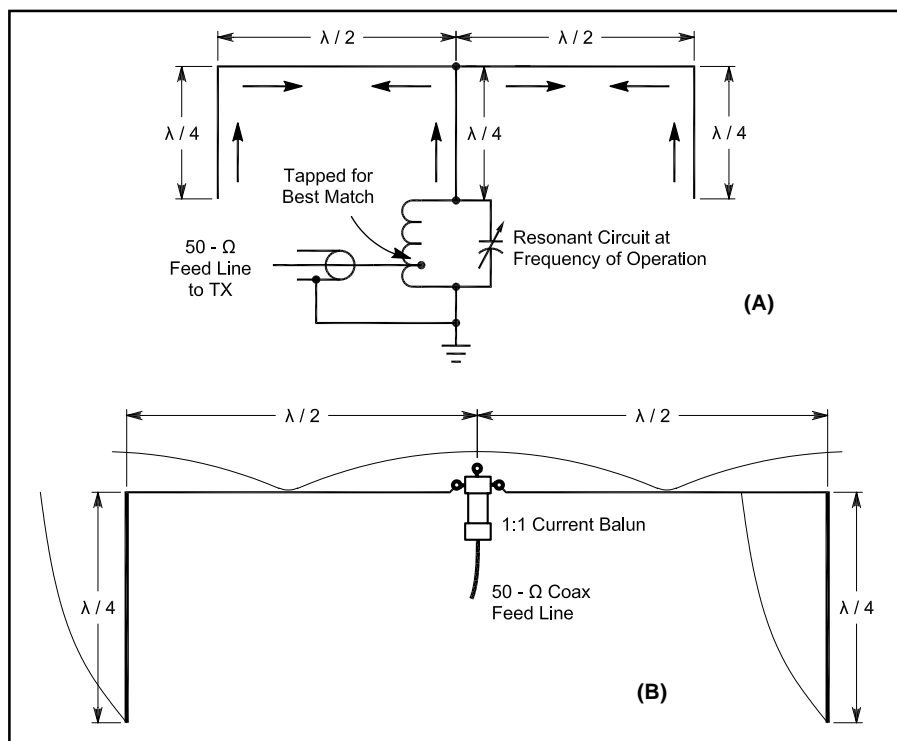


Figure 1—A bobtail curtain (A) compared to the N4GG Array (B). The diagram of the N4GG Array shows current distribution. The antenna is essentially a $\frac{3}{2}$ -wavelength dipole with the outer $\frac{1}{4}$ -wavelength part of each dipole leg hanging vertically.

The elevation radiation patterns for an N4GG Array and a dipole at the same height are shown in Figure 2. The outer circle in the figure is +5.96 dBi. The gains of the antennas are equal at a 23.5-degree take-off angle, but the gain of the N4GG Array is approximately 3.4 dBi higher than that of the dipole at elevation angles of between 10 and 15 degrees, and a whopping 11 dBi higher at 5 degrees.

For DXers, the Array's dismal performance at high take-off angles is just as important as its excellent low-angle performance. For DXers, high-angle reception is simply a source of interference and additional atmospheric noise. Straight up, the gain of the N4GG Array is more than 20 dB below that of the dipole. All of the data presented in this article was obtained using *EZNEC* 3.0, with the ground model set to "average, pastoral heavy clay." The elevation plots shown in Figure 2 are for the azimuth angle yielding maximum gain, which is 90 degrees (broadside) for the dipole, and 40 degrees from the plane of the horizontal wires for the N4GG Array.

A tremendous amount of information has been published lately about the effects of the number of radials used in a particular antenna, elevated radials and ground characteristics on the performance of vertical antennas. Restating it all here is beyond the scope of this article but, in summary, ground radials and the earth itself provide two things for verticals mounted near the ground: (1) a return path for antenna current and (2) a surface that reflects the lower half of the free-space radiation pattern upward, adding to the upper half.

Return-current losses are usually minimized by the use of radials, while radiation reflection losses are determined by the ground conductivity out to 10 wavelengths or more from the antenna (in most cases reflection losses are out of our control). Verticals work well over good-conducting earth and particularly well over or near saltwater. The N4GG Array follows these same principles, and radials aren't required, as the "return current" is within the antenna and nearly lossless.

The actual gain of an N4GG Array over a dipole, however, particularly at low elevation angles, will depend on the height of the antenna above ground and the conductivity of the ground underneath it. Figure 2 shows an installation with average ground conductivity and near-worst-case proximity to the ground. If your location has average ground conductivity you should be able to achieve at least the gain performance shown in Figure 2. Increased height and/or increased ground conductivity will yield even better performance.

Depending on your point of view, the azimuth radiation pattern of an N4GG Array could be considered one of its two

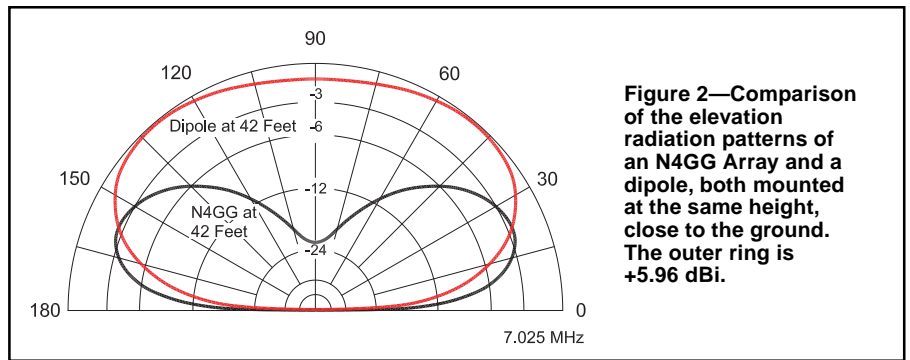


Figure 2—Comparison of the elevation radiation patterns of an N4GG Array and a dipole, both mounted at the same height, close to the ground. The outer ring is +5.96 dBi.

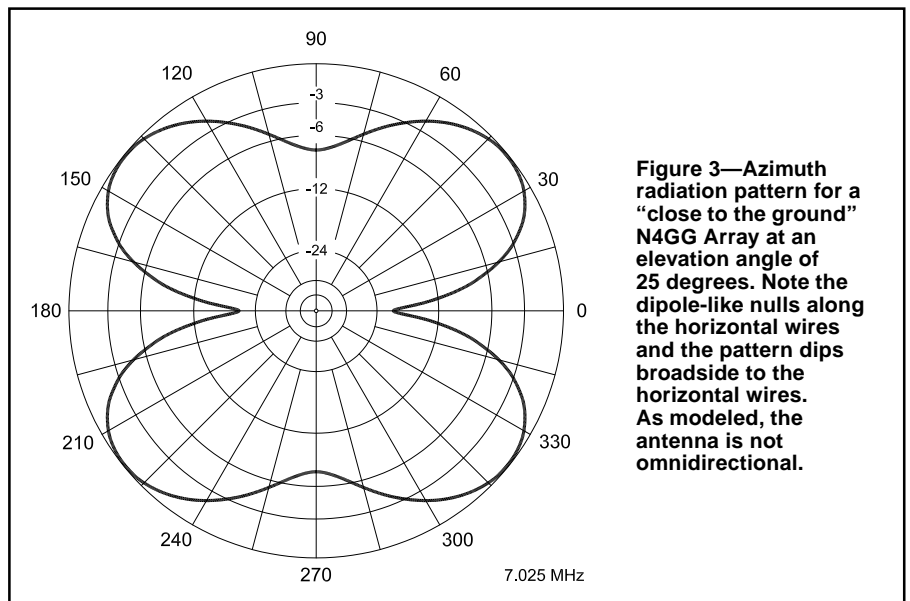


Figure 3—Azimuth radiation pattern for a "close to the ground" N4GG Array at an elevation angle of 25 degrees. Note the dipole-like nulls along the horizontal wires and the pattern dips broadside to the horizontal wires. As modeled, the antenna is not omnidirectional.

drawbacks—the other being that the horizontal size is twice that of a standard dipole. The azimuth radiation pattern for an N4GG Array at an elevation angle of 25 degrees is shown in Figure 3. As you can see, the phased verticals produce nulls both broadside and along the plane of the horizontal wires, together with four peaks that occur at 40 degrees from the horizontal wires. If a truly omnidirectional antenna is what you want, this antenna doesn't quite fill the bill. But how bad is it?

As modeled, the -3 dBi azimuth beamwidth of the antenna is 187 degrees out of 360 degrees, and the deep nulls along the horizontal wires are very narrow and not much different than those of a dipole. The "as modeled" pattern could actually be used to your advantage. At my mid-Atlantic location, an N4GG Array could be positioned to provide peak gain toward Europe, Africa, VK/ZL and JA—not bad! But maybe not so good, either, as the broadside pattern dips would be toward South America and parts of Asia.

The real answer to how objectionable the departure from an omnidirectional pattern is lies in a fuller investigation of the modeled performance, the difference in real antenna performance compared to

idealized models and some on-air observations.

The model indicates that the broadside pattern dips lessen as elevation angle increases. Some DX signals arrive at higher elevation angles, particularly during band openings and band closings on the lower frequencies. More importantly, the models are idealized in all respects except for the characterization of the earth, which is set to a point-estimate that may or may not accurately reflect a specific location. The actual radiation pattern for a real N4GG Array will depend on proximity to local objects, local topology, actual ground characteristics, and so on.

I decided simply to put one up to get some real-world results with respect to the modeled antenna and its theoretical radiation pattern. My on-air observations are at the end of the article, but I can assure you that the strength of long-haul DX signals—from any direction—is nearly always better on my N4GG Array than on a reference dipole at the same height, and is *never* worse than equal. On a receive signal-to-noise basis, the N4GG Array is always better, which is understandable given its lower gain at high elevation angles.

The dimensions for an N4GG Array are L_1 (feet) = $489/f$ (MHz), and L_2 (feet) = $257/f$ (MHz), where L_1 is the length of each of the two horizontal wires, and L_2 is the length of each vertical wire. These formulas are correct for a height of approximately 0.3-wavelength above ground and will vary slightly as a function of height.

As with most wire antennas, it's reasonable to make the antenna a bit larger than the formula suggests (in this case the vertical sections) so the antenna can be trimmed for minimum SWR at the desired operating frequency. Beyond trimming for SWR, the dimensions are not critical to performance. At resonance and at 0.3-wavelength above average ground, the feed-point impedance is 73Ω , providing a near-perfect match for $75\text{-}\Omega$ coax and less than 1.5:1 SWR when fed with $50\text{-}\Omega$ coax. Using $50\text{-}\Omega$ coax, the 2:1 SWR bandwidth on 20 meters is greater than 200 kHz.

Table 1 provides dimensions and some operating characteristics for single-band HF N4GG Arrays. The table values are for arrays where the bottom of the vertical wires are 7 feet above the ground (out of harm's way) and for resonant frequencies where the 2:1 SWR envelope starts at the lower band edge (for bands other than 30, 17 and 12 meters), or at the center of the band (for 30, 17 and 12 meters, which are entirely contained in the 2:1 SWR envelope). The 2:1 SWR bandwidths shown are for $50\text{-}\Omega$ feed line.

An important consideration in achieving reasonable performance is to keep the feed line from radiating and becoming an additional antenna element. This can happen by not using a balun at the feed point to make the transition from an unbalanced transmission line to a balanced antenna. A high-quality 1:1 current-type balun should be used at the feed point to prevent this problem.

A nice feature of an N4GG Array is that the fields from the two vertical radiators cancel at the center of the antenna, resulting in no parasitically induced current on the shield of the coax feed line (at least in theory). In practice, the near-field radiation pattern from the verticals

may not perfectly cancel, and the feed line placement may deviate somewhat from the ideal. Induced current on the coax shield should be sufficiently small to not affect the antenna's performance significantly, however.

Let's Build an Array

Construction of an N4GG is straightforward. Physically this is just a centered dipole of twice the traditional length, with vertical wires at the dipole ends. "Invisibility" and safety dictate the exact construction techniques.

A few words about "invisible" antennas might be useful at this point. My various wire antennas have been built using 18 or 19-gauge galvanized steel wire, which is available at home supply stores and is very inexpensive. Copper would be somewhat better electrically, but the galvanized wire has good strength at nearly invisible diameters. Galvanized wire has only moderate life, however, and will eventually rust and fail mechanically. Copperweld is probably the best choice for strength and life, and it is good electrically.

Strength is particularly important if you're going to build a multiband N4GG, and a critical necessity if you do not have a center support for the feed line and balun. The vertical wires in an N4GG Array only support themselves and can be of a smaller gauge if necessary. Remember, however: the smaller the wire gauge, the narrower the bandwidth.

The galvanized wire takes on a dull gray finish after a few days outdoors, which helps with invisibility. I paint the insulators and the balun with flat gray spray paint. Feeding with RG-8X also helps, and I have found that RG-8X will handle 1.5 kW without problems as long as the feed line SWR is low enough (as it is with this antenna).

My multiband N4GG Array uses trees for skyhooks and a line tossed over another tree limb to support the balun and feed line at a height of 66 feet. The balun is very close to the center support tree limb and the coax runs down the side of the tree that can't be seen from the street.

The antenna has been up for three years and has been detected only once, by a neighbor who strayed onto the property.

The vertical wires can be terminated with insulators and held taut by tying them to ground stakes with nylon or heavy-duty monofilament line. This approach is prone to breaking, however, if you are using trees for end supports, as the wind will cause the antenna to move up and down, stressing the lines and wires. I prefer to simply let the vertical wires hang, using two-ounce fishing weights at the bottom to keep them somewhat taut. This way, the vertical elements tend to swing in a breeze, but this isn't noticeable on the air.

N4GG Arrays can be installed as low as a $1/4$ -wavelength above the ground, but two hazards arise when the vertical ends are lower than about seven feet above the ground. First, the bottom end of the vertical wires are obstacles for people and animals to run into (the use of "invisible" components makes this problem worse). Second, the lower end of the vertical elements are the high-voltage points in the antenna and can cause RF burns to people or animals that may be in contact with them while you're transmitting.

Use common sense during your installation and, if at all possible, install the antenna high enough to keep the bottom ends of the vertical elements above harm's way. If the ends *must* be near the ground, running the wires inside a few feet of 1-inch (or greater) PVC pipe can add significantly to safety, at some expense to stealth. N4GG Arrays can actually be installed even closer to the ground if linear loading, loading coils or capacitance hats are used to shorten the length of the vertical elements.

Simple Multiband Operation

What about multiband? Simple fan-dipole construction allows connecting multiple N4GG Array wire sets to a common center insulator/balun. Figure 4 shows the schematic of a triband 10, 15 and 20-meter N4GG Array. Figure 5 shows the actual antenna, suspended

Table 1
HF N4GG Arrays—Dimensions and Characteristics

Resonant Freq (kHz)	Height (feet)	L_1 (feet)	L_2 (feet)	Bandwidth (kHz) (2:1 SWR at 50Ω)	Max Gain (dBi)	Takeoff Angle (degrees)
1810	147.5	268	140.5	40	4.03	22.5
3525	80	137.5	73	45	3.54	23
7050	43.5	69	36.5	100	3.58	23
10,125	32.6	48	25.6	140	3.89	23
14,100	25	34.9	18	210	4.19	22.5
18,118	21.25	27	14.25	290	4.48	21.5
21,200	19.1	23.2	12.1	340	4.65	21.5
24,940	17.35	19.6	10.35	420	4.79	20.5
28,250	16.3	17.2	9.3	480	4.91	20

Note: The figures here assume that the bottom of the vertical elements will be 7 feet above the ground.

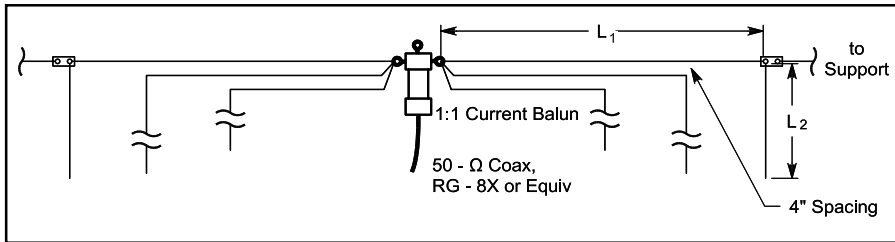


Figure 4—Fan-dipole construction of a 10, 15 and 20-meter N4GG Array.



Figure 5—A tri-band N4GG Array stretched out 3 feet above the ground for easy assembly. Half-inch PVC spreaders are used to separate the wires by 4 inches.

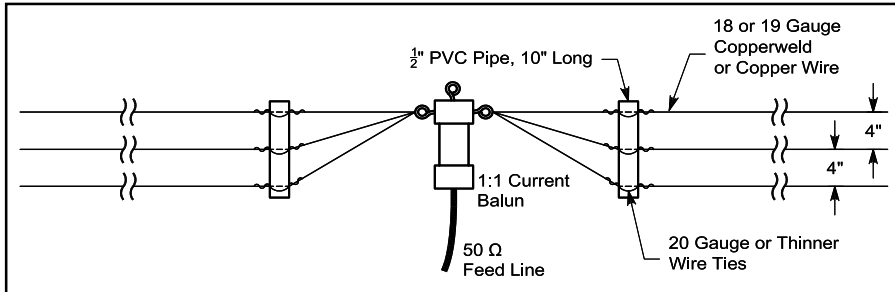


Figure 6—The Array wires travel through the spreaders and are secured with 20-gauge wire ties.



Figure 7—Close-up of the center insulator/balun of a tri-band N4GG Array. Note that all support of the lower wires is provided by the uppermost wires.

about 3 feet off the ground during assembly. Half-inch PVC pipe was used to hold the wire sets 4 inches apart. Figure 6 provides details of how the PVC spreaders were installed.

This is actually a four-band antenna, as the wires that make up the 15-meter N4GG Array are the length of a standard $\frac{1}{2}$ -wavelength dipole on 40 meters. The antenna displays a low SWR on that band, but does not function as an N4GG Array there. On 40, the setup is simply a dipole with bent ends, and offers commensurate performance. The antenna's SWR is below 2:1 on all four bands and does not require the use of an antenna tuner.

Figure 7 shows a close-up of the center insulator/balun. After these pictures were taken, the balun and PVC spreaders were spray painted flat gray.

There is a second approach to multibanding that can yield an N4GG Array from an existing low-band dipole. Figure 8 shows the addition of the vertical wires for a higher-frequency N4GG Array directly onto the horizontal wires of a lower-frequency dipole. In this case no spreaders are used and there is only one connection to each side of the balun. This arrangement works because the vertical wires act as low-impedance stubs, inserted onto relatively high-impedance points on the horizontal dipole.

I added a set of 15-meter $\frac{1}{4}$ -wavelength vertical wires onto an existing 160-meter dipole using this method, getting a second band essentially “for free.” The addition of the 15-meter wires had no measurable effect on the 160-meter dipole. This approach can be used for adding one—or perhaps more than one N4GG Array—onto existing large dipoles. Before you start stitching vertical elements onto your monster dipole, be sure to see how things might play out by modeling the antenna first. For example, a 15-meter N4GG Array can't be added to a 40-meter dipole because they're both resonant on that band!

Actual Performance

Okay, so how well does one of these things actually work? Based on my observations, signals from stations that are more than 3000 miles away are typically a few dB stronger on my N4GG Array than on my dipole at the same height. For long-haul DX, this is the difference between working them and not. I added XU and XW as new countries lately—and I couldn't hear either station on the dipole. When 15 meters is hot, as it is now near the top of cycle 23, I can sometimes call CQ on the N4GG Array and start a pileup of European and Asian stations, something I've never accomplished with the dipole!

Your first impression operating with

an N4GG Array may not be good—mine wasn't. Tuning quickly, the whole band sounded down, both stations and noise. "Something's broken," or "These things don't work as modeled," were my first thoughts. If you put up an N4GG Array and it sounds dead at first, it's working—it's supposed to sound somewhat dead! Most of the signals we tend to hear when quickly tuning a band are close in. These signals—and much of the band noise—arrive at high elevation angles, where an N4GG Array can be 20 dB down from a dipole. After you get over how quiet the band sounds, find a DX station and switch between an N4GG Array and a dipole. That will put a smile on your face! Then try one in a major DX contest and get ready for even more smiles.

Make no mistake, this antenna isn't nearly as good as a decent Yagi. It is, however, the best DX antenna design I've found to date that offers stealth, low-angle radiation (even when installed close to the

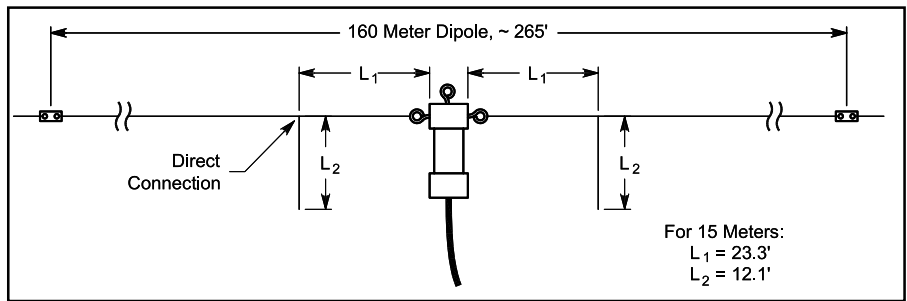


Figure 8—A higher-frequency N4GG Array can be formed by adding $\frac{1}{4}$ wavelength vertical wires to a lower-frequency dipole.

ground), tuner-free multiband operation when fed with 50- Ω coax, radial-free installation, simplicity and affordability. That's a lot of benefits in one package!

Photos by the author.

Hal Kennedy, N4GG, is the Vice President for Technology Commercialization at Lockheed Martin Corporation. He was first licensed in 1961 and holds an Ama-

teur Extra license as well as a General Radiotelephone license. He received a BSEE degree from Lafayette College and an MS in Management from The Sloan School at MIT. An ARRL and PVRC member, Hal spends his time DXing, contesting and trying to improve his signal from a suburban lot. The author may be reached at 110 Fox Trail Terr, Gaithersburg, MD 20878; n4gg@hotmail.com.

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FEEDBACK

◇ Through no fault of the authors, K1KP and N2EA, the caption of Figure 1 in "The ICOM 756PRO—A Cure for the Rumble" (Technical Correspondence, June 2002, page 68) is incorrect. It should read "Add a capacitor to cure audio rumble in the ICOM IC-756PRO" (and not the PROII as stated). The authors did not claim that the IC-756PROII had any audible rumble. The figure correctly shows the main board of the '756PRO. Also see the ICOM "Tech Talk" on page 149 in this issue for a response by ICOM to this Technical Correspondence.

◇ The right-hand photo in "At the Foundation," May 2002, p 100, was taken by Andrew McLuckie, K3AWM. The young man in the center of the photo is Brian Edelman, who made 22 contacts during his first on-the-air experience at the scout camp in Pennsylvania.—K3AWM

◇ The title of the book written by "VC" Angell, KCØEM [Strays, Jun 2002, p 50] is *The Last Holey Man*.

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