The Case of Declining Beverage-on-Ground Antenna Performance

Over the course of two winter seasons, the performance of this antenna dropped off dramatically. Here's why.

Rudy Severns, N6LF

In midsummer 2013, I placed 450 feet of insulated wire in my pasture as a Beverage on the Ground (BOG) receiving antenna. I was using it to receive WSPR signals, which provide signal-to-noise ratio (S/N) estimates. Over time, and especially during two intervening wet winter seasons, I noticed that received signals dropped off by 15 dB and the S/N of the BOG was no better than that of a simple vertical. I carefully checked connections, feed lines, and associated hardware, but found no problems. This rather radical decline in performance seemed a mystery.

There has been skepticism regarding the validity of using *NEC* modeling of antennas with wires close to ground. Over the years, I've often compared my modeling predictions with finished antennas and generally found very good correlation, but the skepticism prompted me to ask if the latest version of *NEC* (*NEC-4.2*) models antennas with wires close to, or buried in, soil well enough to explain my declining BOG performance. Thus I needed to experimentally validate *NEC-4.2* modeling before I could confidently move on to my BOG problem. I performed a series of experiments with actual antennas having wires parallel to the soil at low heights, and wires buried in soil. I measured the feed-point impedances and soil electrical characteristics.

I'm interested in antennas for 80, 160, and 630 meters, so my test frequencies ranged

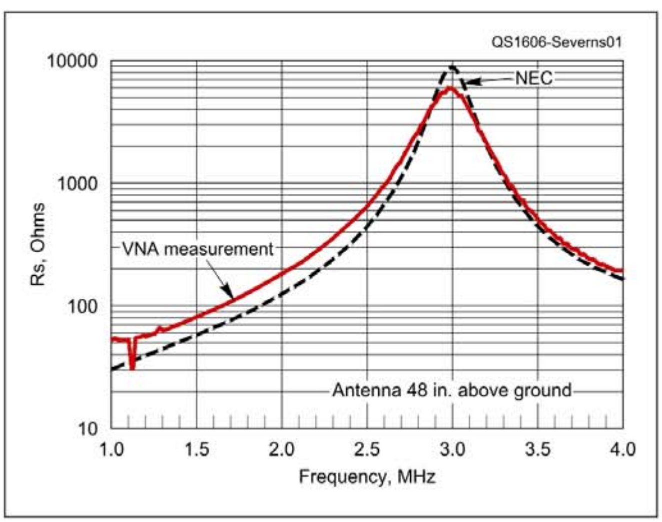

Figure 1 — Measured (red) and modeled (dashed) feed-point resistance of a 300-foot center-fed dipole 48 inches above ground.

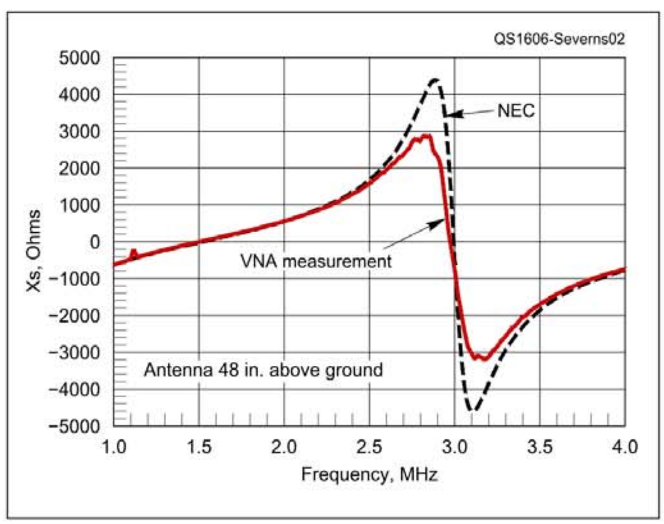

Figure 2 — Measured (red) and modeled (dashed) feed-point reactance of a 300-foot center-fed dipole 48 inches above ground.

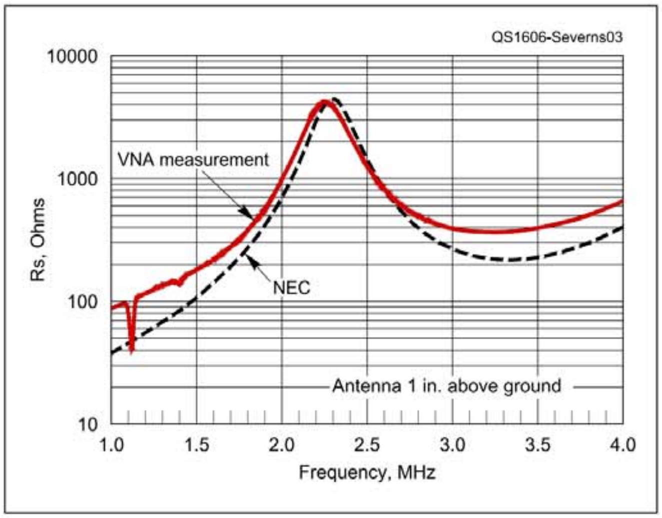

Figure 3 — Measured (red) and modeled (dashed) feed-point resistance of a 300-foot center-fed dipole 1 inch above ground.

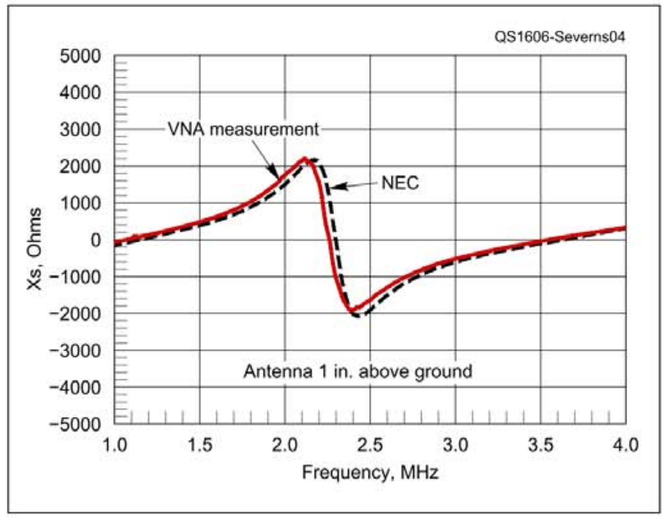

Figure 4 — Measured (red) and modeled (dashed) feed-point reactance of a 300-foot center-fed dipole 1 inch above ground.

from 400 kHz to 4 MHz. The examples do not cover all possibilities, but they're representative. Here is what I found.

Modeling and Instrumentation

NEC solves for the currents on the wires, and from these currents calculates both the feed-point impedance and the radiation pattern. If the impedances calculated from the *NEC* model agree with the values measured on the actual antenna over a wide range of frequencies, you can be reasonably sure the modeling is reliable. In the case of my BOG, which was partially buried, it was helpful to see if *NEC* could predict the current distribution along the wire at a given frequency (1.83 MHz). For the modeling I used *EZNEC* and *Auto EZ*.[1, 2] I used a vector network analyzer (VNA) to measure impedances. In the graphs, I've made it a point to display the raw measurements without any corrections to the data points. You can see noise present on the graphs, particularly at frequencies associated with local broadcast stations. I measured the soil electrical characteristics concurrently with the feed-point impedances. The following discussion addresses *NEC-4.2* only, because *NEC-2* does not allow buried wires and does not handle wires close to ground very well.

Test Antenna #1

The first test antenna was a low center-fed dipole. I chose a 300-foot length that allowed the antenna to present both odd (like a series resonance) and even (like a parallel resonance) multiples of a half wavelength, presenting a range of high and low feed-point impedances. I varied the height above ground from 48 inches (see lead image) down to 1 inch. Figures 1 and 2 show the comparison between *NEC* predictions and measured feed-point resistance and reactance for the antenna 48 inches above the ground. Figures 3 and 4 repeat the comparisons 1 inch above ground. Evidently, *NEC* does a very good job modeling the impedance of an antenna down to 1 inch above ground.

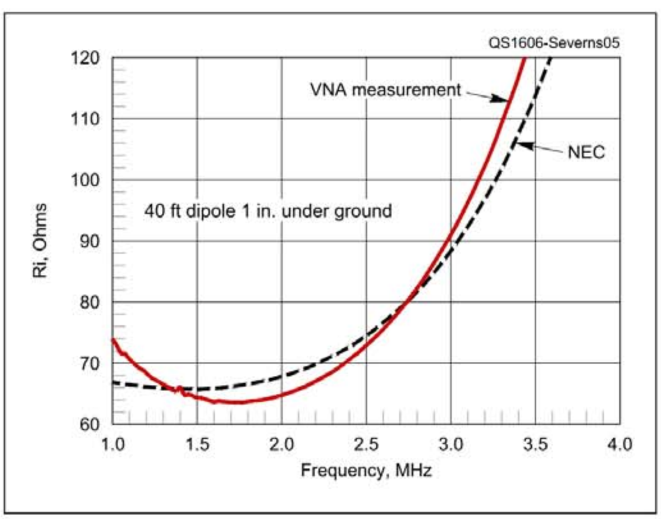

Figure 5 — Measured (red) and modeled (dashed) feed-point resistance of a 40-foot center-fed dipole made from insulated #26 AWG wire buried 1 inch below ground.

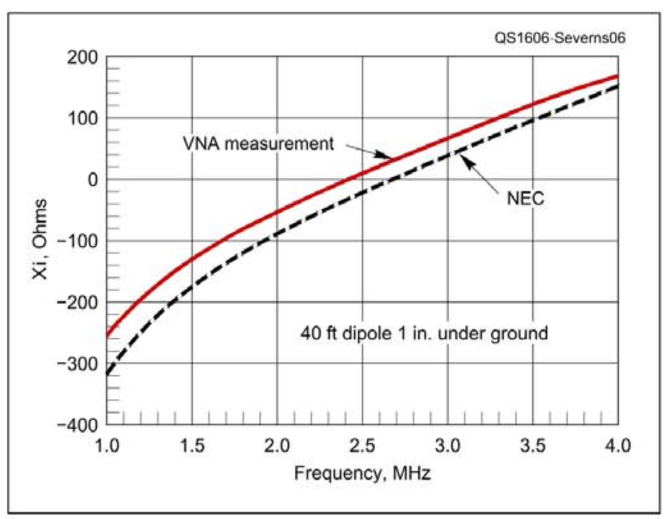

Figure 6 — Measured (red) and modeled (dashed) feed-point reactance of a 40-foot center-fed dipole made from insulated #26 AWG wire buried 1 inch below ground.

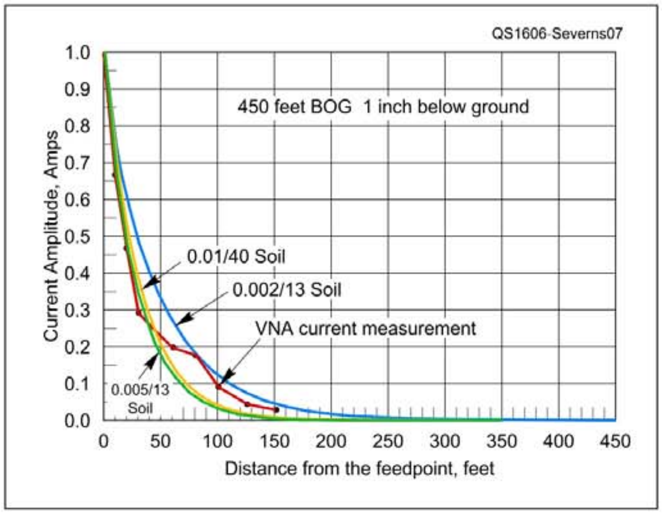

Figure 7 — Measured (red) and modeled (dashes) RF current amplitude at 1.83 MHz along the 450-foot BOG antenna buried 1 inch below ground.

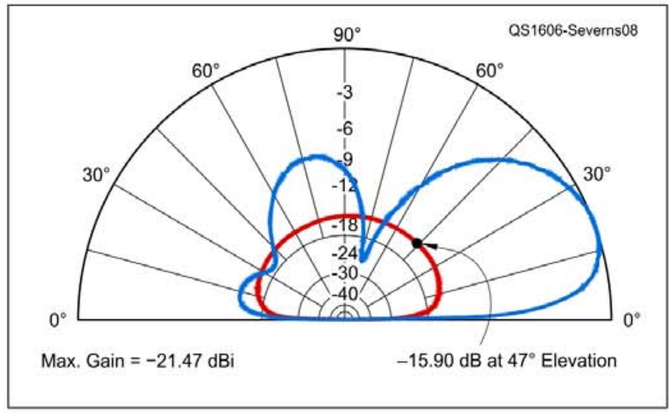

Figure 8 — Elevation radiation patterns for the BOG 1 inch above ground (blue) and 1 inch below ground (red).

Test Antenna #2

My second test antenna was a 40-foot-long dipole made from #26 AWG insulated wire, and buried 1 inch below ground surface. Although only 13% as long as test antenna #1, the resonant frequency is still close to that of the 300-foot dipole above ground. Placing an antenna very close to or in the soil drastically reduces the resonant frequency. Figures 5 and 6 show the resistance and reactance results for antenna #2. The correlation between *NEC* calculations and VNA based measurements indicate that the modeling provides reasonable predictions.

Test Antenna #3

I wanted to test an antenna that incorporated a ground rod to get a feeling for how well ground rods are modeled. I have a pair of tall wooden support poles, so I simply suspended a vertical 77-foot length of insulated wire from the midpoint of a Dacron line stretched between the poles. Overall agreement was very good and the predicted resonant frequency was particularly close.

Test Antenna #4

This entire exercise was prompted by the mysterious declining performance of my BOG, so my final test antenna was the BOG itself. I measured feed-point impedances from 400 kHz to 4.4 MHz, as well as the current amplitude and phase along the wire at 1.83 MHz. Again, the impedance measurements were close to predictions. I added the current measurements as a further confirmation of *NEC* modeling. I modeled the antenna 1 inch below ground to account for its actual burial over time. A comparison between modeling and measurement for the current distribution is seen in Figure 7. The correlation between measurements and modeling is good despite the inherent uncertainties in the ground surface modeling and the variation in soil electrical characteristics along the 450-foot length of the antenna.

If the impedances calculated from the *NEC* model agree with the values measured on the actual antenna over a wide range of frequencies, you can be reasonably sure the modeling is reliable.

The rapid exponential decay of the antenna current predicted by *NEC* was a surprise to me, but field measurements confirmed it. This goes a long way towards explaining why the performance became so poor. Functionally, the partially buried BOG behaves more like a radial than an antenna! Disconnecting the ground rod at the far end had no effect on either current distribution or feed-point impedance, because there was very little if any current at the far end of the antenna.

At this point, I modeled the BOG at heights of 1 inch below and 1 inch above the ground to approximately represent the changes from the time the BOG was first installed to the present, and to see how the radiation patterns might have changed. Those patterns are compared in Figure 8.

Figure 8 solves the initial mystery. The larger (blue) pattern represents the initial condition of the antenna 1 inch above ground. The receiver directionality factor (RDF) is 12 dB and a peak gain Gp is –21.5 dB. The smaller pattern (red) represents the present BOG condition 1 inch below the ground. The RDF is 6 dB and Gp is –37.4 dB. These patterns make it clear just how severely the performance declined as the BOG gradually sank into the sod and soil through two winters. The differences in the pattern shown in Figure 8 correlate well with the S/N estimates observed over time.

Conclusions

Correlation between measurements and modeling was excellent in the four examples. These representative examples cover a range of practical cases using very low and buried wires. From this and earlier work, I conclude that *NEC* modeling gives reliable results if we use *NEC-4.2*, follow *NEC* modeling guidelines closely, make sure that the model is dimensionally as close as possible to the actual antenna, and we perform careful soil measurements.[3, 4, 5] The practical limitations of *NEC* modeling are not computational shortcomings in the *NEC* code. What limits us is our knowledge of the details of the actual antennas and the associated soil characteristics, and our ability to replicate these in a model. A more detailed study is available on the *QST* in Depth web page.[6]

As a practical matter we can never be perfect, but careful modeling will get us close. The BOG can be a very useful receiving antenna, but your results may vary. If your BOG is slowly covered by what grows around it, or what falls from the sky, you might see significant degradation over time. The cure is simple. Inspect the antenna regularly and pull it out of the weeds as needed.

Acknowledgments

This work was prompted by an e-mail from Al Christman, K3LC, relaying a question from Carl Luetzelschwab, K9LA, regarding the reliability of *NEC* modeling for wires close to or on the surface, or buried. I express my sincere appreciation to both Roy Lewallen, W7EL, and Dan Maguire, AC6LA, for the use of their latest software. I also thank Don, N4DJ; Greg, W8WWV, and Carl, K9LA, for reading and commenting on earlier versions of this article.

Notes

[1]Several versions of *EZNEC* antenna modeling software are available from developer Roy Lewallen, W7EL, at **www.eznec.com**.

[2]*AutoEZ* automates use of *EZNEC*; see **www.ac6la.com**.

[3]Rudy Severns, N6LF, "Experimental Determination of Ground System Performance for HF Verticals," *QEX*, in seven parts, Jan/Feb 2009 pp 21 – 25 and pp 48 – 52, Mar/Apr 2009 pp 29 – 32, May/Jun 2009 pp 38 – 42, Jul/Aug 2009 pp 1 – 3, Nov/Dec 2009 pp 19 – 24, and Jan/Feb 2010 pp 18 – 19.

[4]Rudy Severns, N6LF, "An Experimental Look at Ground Systems for HF Verticals," *QST*, Mar 2010 pp 30 – 33.

[5]Rudy Severns, N6LF, "A Closer Look at Vertical Antennas With Elevated Ground Systems," *QEX*, Part 1 Mar/Apr 2012 pp 32 – 44, Part 2 May/Jun 2012 pp 24 – 33.

[6]**www.arrl.org/qst-in-depth**

Photo courtesy of the author.

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New Products

Lightweight Baluns from SOTABEAMS

The Pico Balun from SOTABEAMS is a 1:1 current balun or 4:1 matching transformer and antenna feed point assembly available in kit form. The transformer is mounted on a printed circuit board that allows easy attachment of the antenna and feed line. Specifications include a common mode impedance of more than 1000 Ω from 5 MHz to 30 MHz, 10 W power rating, and weight of about 1 ounce. Price: about $9. For more information, visit **www.sotabeams.co.uk.**

DXtreme Reception Log X Software

DXtreme Reception Log X (version 10) is a *Windows* logging program for radio monitoring enthusiasts. In addition to the usual logging functions, the software integrates Afreet *Ham CAP* for propagation predictions. The program also features an integrated QSL imaging facility that allows users to scan physical QSL cards and capture electronic QSLs received over the Internet. A dedicated tab on the Reception Log window allows users to associate photos or other images with log entries. An embedded audio feature lets users maintain an audio archive of stations heard. The Schedule Checker lets users import schedules from Aoki, EiBi and FCC AM websites and filter and display the data. The software includes a customized paper and e-mail reception report generator. Price: $89.95. Upgrade pricing is available. For more information, or to order, visit **www.dxtreme.com**.