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How Dipoles Radiate— The Hiker’s Bent Dipole

Pedestrian HF mobile is a delightful way to combine amateur radio with trail hiking. In the previous Ionospherica we the big picture of the Earth-Sun system that governs the behavior of the ionosphere. We also saw how reflections from earth interact with an antenna to form vertical standing waves that vary the signal strength at different antenna heights. But what if the antenna is at ground level? What if half of the antenna lies on the ground? Ed Breneiser’s, WA3WSJ, pedestrian mobile trek inspires this episode [1]—the hiker’s antenna and its radiation properties. The concepts carry over to other antenna that use a counterpoise.

The hiker’s antenna seen in Figure 1 comprises two antenna elements. One is a vertical whip above the backpack radio, and the second is a wire that drops to the ground and trails behind the hiking radio operator. Since both the vertical whip portion and the trailing wire portion contribute to the radiation, the antenna pattern of this “bent dipole” is far from omni-directional.

The stylized envelope surrounding the hiker suggests a directional antenna pattern. A hapless bird behind the hiker “feels the heat”, while the “who-ing” owl in front remains less than well illuminated. This is the story of how the hiker’s bent dipole radiates, its directional characteristics, and how it couples to the ionosphere.

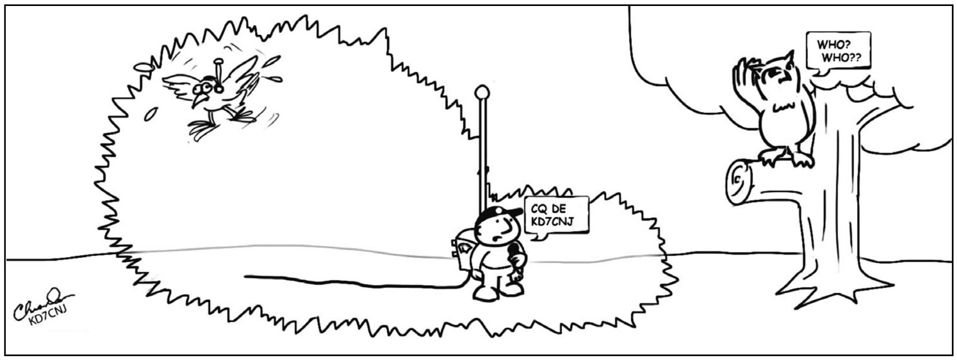

Figure 1—The hiker’s HF portable antenna has two elements: a vertical whip, and a trailing wire. These elements form a bent dipole that has directional properties. ***Copyright © 2014 Chris Dean, KD7CNJ, used with permission***

We’ll confine our discussions to wire antennas with elements that are each generally less than a quarter wave long, but otherwise this story is relatively independent of frequency. Also, we don’t require that the wire elements self-resonate. That’s a detail we handle by antenna matching circuits, or with an automatic antenna tuner.

It Takes Two to Tango

Dipoles by definition have two ends. Radiating electric fields connect between those two end points to radiate. Said another way, there are no monopole antennas in isolation. However, an image of the antenna in a “mirror” such as a perfect electric conductor (PEC) can take the place of the second element. However we do it, there must be a counterpoise below the whip element protruding from the backpack radio—a second dipole element.

Figure 2 portrays the electric fields of (A) a dipole, (B) a monopole with a perfect image in a PEC of infinite extent, and (C) a bent dipole entirely above an earth ground. The dipole is in isolation, that is, it is not near ground. There is a certain symmetry in the elements, but they need not be

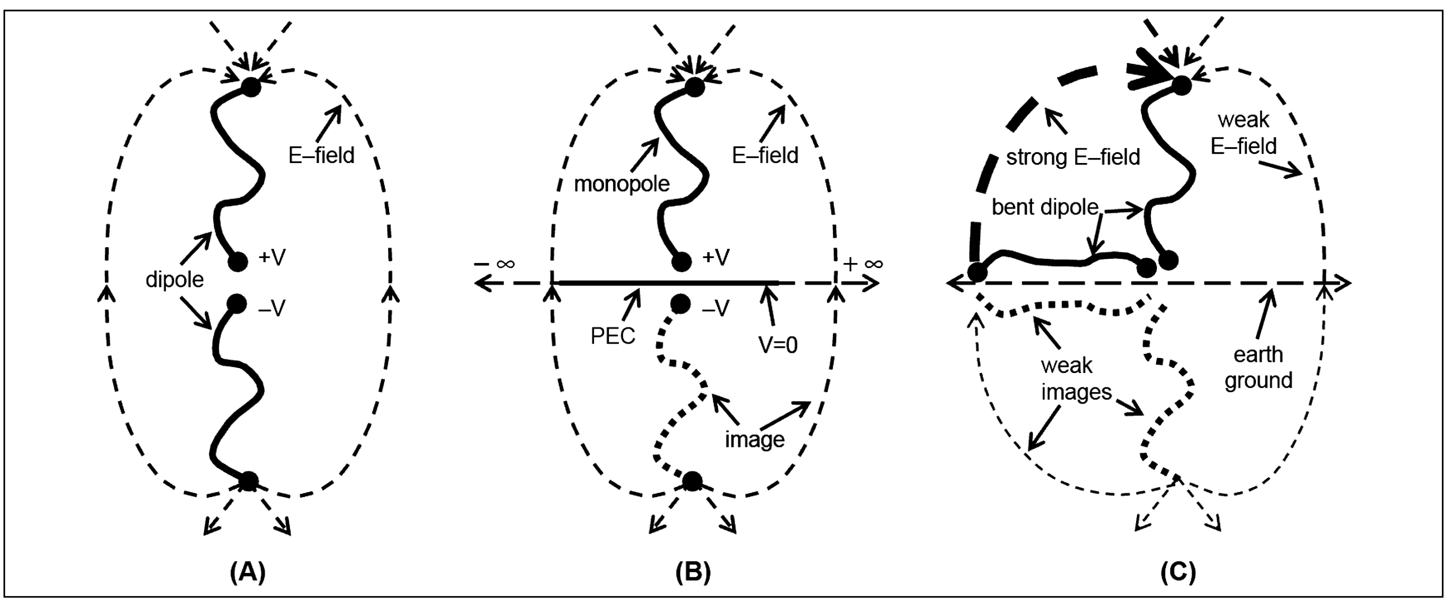

Figure 2—An electric antenna, like a dipole (A), needs two ends or tips that attach the E-field lines between them. In an arrangement (B) over a PEC one half of the dipole appears as an image in the PEC, including image fields. A bent dipole (C) above an earth ground has a weak image in the ground, and weak image fields, and has directional properties.

straight, and they may include loading elements such as inductors. Apply a balanced voltage, +V and –V to the feed terminals of the dipole. The electric fields that appear around the dipole seem to emanate primarily from a pair of "point sources" at the two tips of the dipole elements. These fields are depicted by dashed lines in Figure 2. Note that the fields, like those between the plates of a capacitor, originate at one end and terminate at the other end of the dipole. That holds true whether the dipole is in isolation (A), or is a an element against a counterpoise (B), or is a bent dipole (C) near the ground.

Indeed, this two-point source picture conforms with the exact mathematical expression for the total fields of a half-wave long dipole fed at a single frequency [2]. It takes a pair of terminals to feed the dipole. It takes two end points to radiate the electric field.

What if Earth Were a Copper Sheet

We can rely on a mirror image to take the place of the lower dipole element as in the configuration in Figure 2 (B). The monopole, of course, is not a complete antenna. It needs an image in the mirror—a counterpoise. We feed that antenna with an unbalanced voltage +V against a PEC (or our imagined copper Earth). The PEC provides the second terminal for the return current path of the feeding voltage +V. It also provides the mirror image of the monopole tip, with its opposite charge, so that the electric fields can terminate properly and therefore radiate.

How much of a counterpoise do we need? We've portrayed an infinite half space of PEC in Figure 2 (B). However, we can get away with far less. That leads us to the Hiker's Bent Dipole

The Hiker's Bent Dipole

The vertical whip element and a wire trailing on earth ground is about as minimalist as one can get to realize a dipole for the trail-walking backpacking radio-toting ham. We portray that dipole in Figure 2 (C). Now the earth ground is not perfect, the ground images are weak, but we do have two elements with two distinct end points, and we have two feeding terminals.

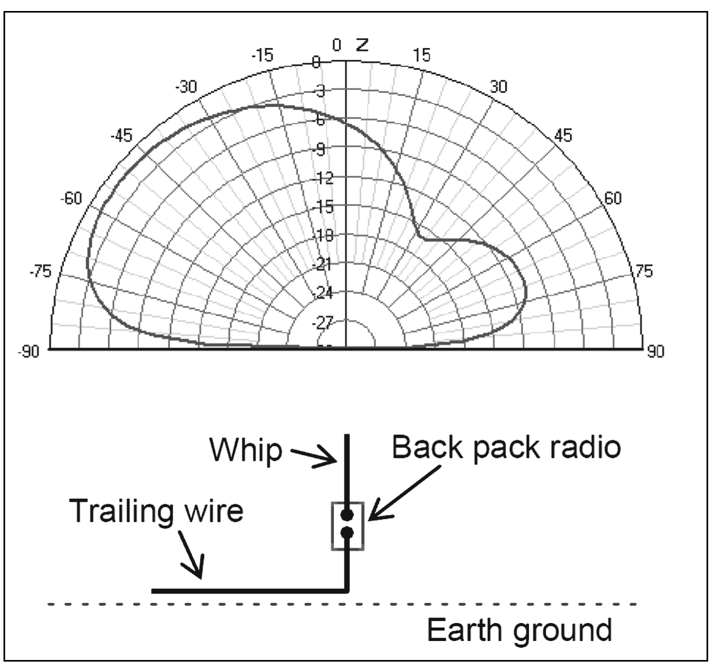

Figure 3—Calculated elevation pattern of the Hiker's Bent Dipole. The rear to front ratio is nearly 10 dB.

We've lost the symmetry evident in (A) and (B), but we've gained a configuration that is very suitable for pedestrian mobile—a dipole with a vertical whip element and a trailing wire element. Both elements are equally important to the radiation process. As depicted in (C), the bent dipole will tend to have a comparatively strong electric field joining the two wire ends, and weaker fields interconnecting the weak images in the real earth ground.

Consequently, the the bent dipole will favor radiation in the direction of the trailing wire.

Antenna Pattern of the Hiker's Dipole

We can simulate the performance of the Hiker's Bent Dipole using Numerical Electromagnetic Code (NEC), such as EZNEC [3], or 4NEC2 [4] using the geometry shown in Figure 3. The pattern in the plane of the bent dipole has a back to front ratio of nearly 10 dB. The back to side ratio is about 5 dB. Thus the hiker experiences about two S units stronger signals from behind compared to the front, and about one S unit lower to the sides compared to the rearward direction.

The pattern seen in Figure 3 has a broad elevation pattern peak between about 15 and 60 degrees above the horizon, and has significant signal coverage down to 5 degrees above the horizon. That's suitable for coupling into the ionosphere for long distance communications as well as for shorter hops.

While this "hiker's beam" antenna requires some additional hiking to make it rotate, at least now you know the favored pattern directions.

Estimating Radiation Patterns

Figure 2 provides us with some insights into how we can qualitatively estimate radiation patterns and radiation polarization. Rather than worrying about how the currents flow in the wires, observe how the E-fields must form to connect the farthest two ends of a dipole. From Figure 2 (C) we can estimate that the polarization in the rear and front directions is essentially vertical. However, the fields emanating to the sides of the hiker are polarized half-way between vertical and horizontal.

Summary and Conclusions

The bent dipole model lets us estimate the performance of the hiker's antenna very conveniently. Peak signals with a broad elevation pattern are behind the hiker, and antenna polarization varies from vertical to the rear and front, to a significant tilt towards the sides. We can use the same technique to estimate the radiation properties of mobile antennas.

References

1. E. R. Breneiser, WA3WSJ, "Colorado QRP Pedestrian Mobile or Bust." *QRP Quarterly*, Winter 2014.

2. K. Siwiak and Y. Bahreini, *Radiowave Propagation and Antennas for Personal Communications*, Third Edition, Artech House, Norwood MA: 2007, Chapter 11.

3. EZNEC from R. Lewallen, W7EL, available at www.eznec.com

4. 4NEC2 from A. Voors, available at www.qsl.net/4nec2/

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