By Brian V. Cake, KF2YN

The "C Pole"—A Ground Independent Vertical Antenna

KF2YN takes the vertical to new heights with this folded design that doesn't require a counterpoise.

When I moved to my new home on the coast of northeast Florida, it was into a deed-restricted community, where "unsightly antennas" were forbidden. I enjoy occasional operation on the HF bands (principally 14 MHz and above) and the location was just begging for the use of vertical antennas, where the proximity to the water would help with good low radiation angles. The verticals could be hidden in the upper deck support structure and everybody would be happy, including my wife.

Unfortunately, the old saw about vertical antennas radiating equally poorly in all directions has a lot of truth to it and losses in the ground system can eat up much of your power. I made the mistake of attempting to measure the ground conductivity in my backyard. That was after I compared the on-air performance of a vertical half-wave dipole for 10 meters with a simple quarter-wave vertical with no radials. I was shocked at the quarter-wave vertical performance. I was even more shocked when I measured 30 kΩ between deep rods spaced 2 feet apart in my back yard.

Conventional solutions to this problem involve the use of radials or counterpoises, but I didn't want to sprinkle the lawn with wires. A full-size vertical dipole, at 30 plus feet for 20 meters, is too high for this location.

With all of these considerations in mind I went looking for another solution, and found an interesting configuration. It is ground independent, has a ground-level 50 Ω feed point, is less than half the height of a full-size half wave dipole, is very efficient, and has a 2:1 SWR bandwidth of about 3 percent. It can be suspended from any convenient support, rolls up into a tiny space and makes a good Field Day antenna.

Basics

The antenna consists of a vertical half-wave dipole that has been folded virtually in half, as shown in Figure 1. By erecting this just above ground level the ground currents are reduced dramatically over those of a quarter-wave ground-mounted monopole. The H-plane radiation pattern for this antenna is virtually omnidirectional.

As shown in Figure 1, the antenna is symmetrical about the feed point and is known as an open folded dipole. The feed-point impedance can be altered by changing the ratio of the diameters of the vertical wires. My intention, however, was to use suspended wire as the elements. The antenna can be analyzed in much the same way as a conventional folded dipole, and it turns out that it can be treated as a short dipole loaded by means of a short-circuited length of transmission line. I decided to take the easy way out and model it using *EZNEC*, however.

There are two practical problems with the antenna in Figure 1: The feed-point impedance is too low and the feed point is in the wrong place. The feed-point impedance depends on the geometry, but for spacing between the vertical wires of about 20 inches on 15 meters the feed-

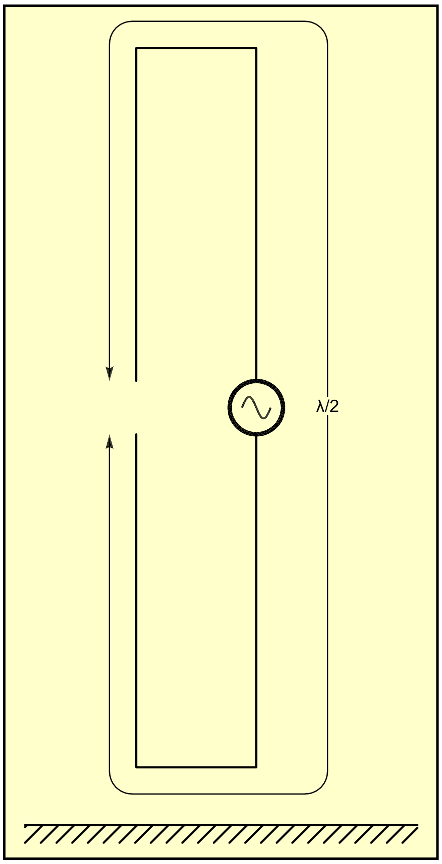

Figure 1—A vertical half wave dipole bent virtually in half.

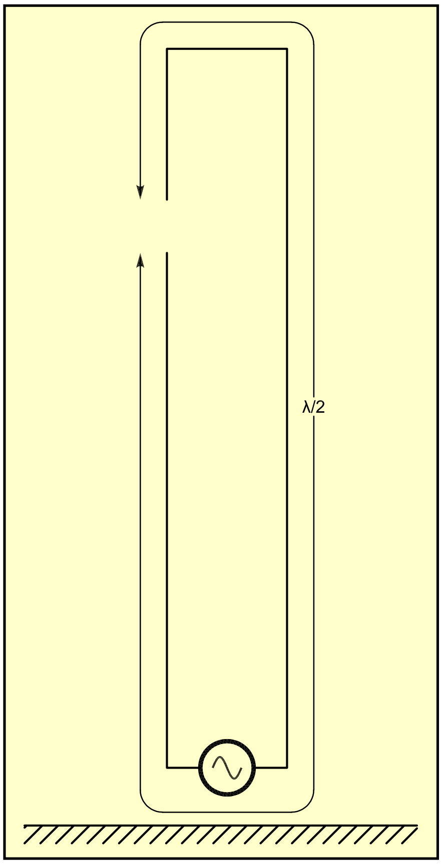

Figure 2—The bent dipole with a shifted feed point.

Table 1
Dimensions (in Inches) of the Modeled Antennas
Wire diameter is $^{1}/_{16}$-inch.
Height of lower horizontal wire is 12 to 24 inches (non-critical).
See Figure 3 for dimensional details.

Band (Meters)	*2:1 SWR Bandwidth (kHz)*	*Dimension* A	*Dimension* B	*Dimension* C	*Dimension* D	*Dimension* E
20	400	177	85	84	8	40
17	540	137	66	67	4	31
15	600	124	60	60	4	20
12	800	100	53	43	4	23
10	800	87	46	37	4	20

point impedance is about 25 Ω. This has to be transformed up to 50 Ω. Also, it is highly desirable to have the feed point at ground level, since otherwise the feed cable has to be dressed away from the antenna such that currents are not induced into the feeder. These currents can lead to undesirable effects of RF in the shack and a modification of the radiation pattern. A ground-level feed point is nicer too, because the cable can be buried a short distance under the lawn.

Both of these problems can be fixed by rearranging the antenna as shown in Figure 2. Moving the feedpoint away from the voltage node at the antenna center increases the feed point impedance and an exact match to 50 Ω can be obtained by shifting the position of the gap at the dipole ends. Unfortunately, doing this places the feed point at a position where there is a substantial common-mode potential. That is to say, the two antenna feed-point terminals have the same potential on them relative to ground (in addition to the normal differential potential across the feed point), and this potential can be several hundred volts for an input power level of 100 W. If the coax is connected directly to the feed point, the natural resonance of the antenna is destroyed and it becomes useless. There are several ways to solve this problem, including the use of an inductively coupled loop, but I chose to use a balun.

The Balun

The only problem with the balun is that it has to work with a high common-mode potential at the feed point and this can lead to trouble. In particular, some baluns that use ferrite cores can cause power loss and intermodulation distortion under conditions of high common-mode potential. This fact is not emphasized in the balun literature, but is important for all antennas with a feed point that is not at a voltage node, such as unbalanced dipoles, off center fed dipoles and multi-band long wires. I have designed two different baluns for these antennas:

1) A simple air-core balun consisting

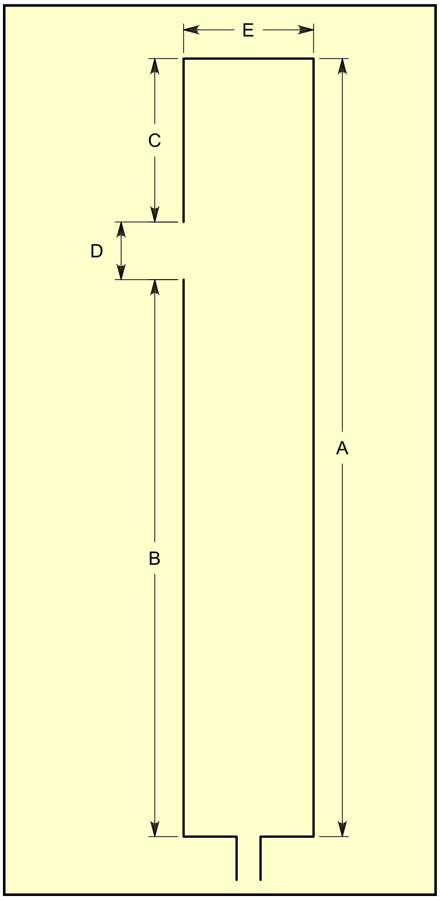

Figure 3—Dimensional details of the antennas. See Table 1.

of 60 turns of RG-58/U close-wound on a 2 inch diameter length of PVC pipe (about 33 feet of RG-58/U total) provides excellent choking action and reduces the line current to about $^{1}/_{10}$ of the feed point current. This will work fine from 14 MHz to 30 MHz, but soaks up a fair bit of power, mostly in cable losses. The total losses are about 14% (about 0.6 dB) on 20 meters and rise to about 18% (about 0.8 dB) on 10 meters. This balun does have the advantage that a quick trip to RadioShack and your local hardware store can provide the materials you need.

2) An alternative design using ferrite toroids reduces the power loss by over a factor of two to <7% (0.3 dB) on all bands. Two different designs, one for 20 meters and the other serving 17 meters and above, are needed in order to keep the core power loss low. The 20 meter balun consists of 19 turns of RG-174/U coax on an FT-240-61 core. For higher frequencies use 15 turns of RG-174/U on an FT-240-67 core. It is possible that a close-spaced winding of the same number of turns of 14 gauge or similar wire will give lower loss than the RG-174/U and will also handle higher power, but I have not tried it.

Antenna Construction

The dimensions for the 20, 17, 15, 12 and 10 meter bands are shown in Table 1. Refer to Figure 3 for the dimensional key. You will note that the spacing between the vertical wires is 20 inches for 15 and 10 meters, but 40 inches for 20 meters. This is because I wanted to squeeze the antenna into available space. Twenty inches would also work fine for 20 meters as long as you adjust the vertical length of the wires.

The dimensions given are those used in the models. Note that the actual dimensions will vary from these. This is because of the effects of support structure, the proximity to objects nearby and the effects of ground on the feed point impedance. My antennas for both 15 and 20 meters resonated too low in frequency and had to be shortened quite a bit. This was partly because I used PVC covered wire and partly because they were hung close to the upper deck. The dielectric constant of the wood reduced the antenna's resonant frequency.

The antenna element can be made of anything from thin, PVC covered copper wire up through aluminum tubing, with suitable small changes in the element lengths. Thin wire will have higher losses than fat wire and will also have a higher common mode potential at the feed point. On 15 meters the loss attributable to the element resistance is 0.57 dB (14% power loss) when 32 mil (20 gauge) copper wire is used. This drops to 0.3 dB (7% loss) when using $^{1}/_{16}$ inch copper, and to 0.15 dB (3.5% loss) for $^{1}/_{8}$ inch copper. I used PVC covered wire because bare copper wire looks ugly after exposure to a beach atmosphere for even a short while. Also note that the balun choke reactance will change the resonant frequency of the antenna somewhat. An inductance of 25 µH on 20 meters will shift the resonant frequency upward by about 1.7%, or 250 kHz.

Assembly

The assembly method I used is shown in Figure 4. Here, suitable lengths of 3/4 inch schedule-40 PVC pipe are used as the top and bottom spreaders, with the element wire simply pushed through the tubes. The spacer in the gap is a 6 inch piece of the same tubing, with holes drilled right through at 4 inch spacing (10 inches and 8 inches respectively for the 20 meter version). Start construction by cutting each piece of the element wire to the dimensions shown, plus 2 feet or so. This additional length allows for securing the wires to the spacer and for adjustment of the resonant frequency and of the SWR. Make the spreaders and the spacer as shown. Drill suitable holes in the top spreader for a suspension cord, if that is the way you are supporting it. Drill two holes near the center of the lower spacer to allow the wires to exit the spreader at the feed point. It is also advisable to drill a few holes in the spreaders to allow water to exit.

Lay the spreaders out in their approximate positions on the ground and thread the wires through them. Temporarily secure the wires at the feed point with tape. Make the balun and solder the feed point wires to the balun cable. Once you have made any adjustments necessary you should seal these joints against the ingress of water. Hoist the antenna into position, and pull on either vertical wire in order to get the lower spreader horizontal. The base of the antenna can be anything from 1 foot or so off the ground to as high as desired. The ground rod shown is not essential—it is useful for anchoring the balun so the base of the antenna doesn't flap in the breeze.

You can now test for resonant frequency and SWR. It is unlikely that you will get it exactly right the first time but, if you are using bare copper wire and the antenna is in the clear, then with the dimensions given it should be pretty close. If the resonant frequency is too low, lower the antenna (or use a stepladder), untwist the wires above and below the spacer, and shorten the element by an equal amount on either side of the spacer, then retwist the wires.

Once the resonant frequency is right, check the SWR. If your SWR meter indicates that the feed-point resistance is too high, then it is necessary to raise the position of the spacer. This is easily done by untwisting the wires, and moving the spacer farther up the top wire. Be sure to keep the total wire length unchanged, or the resonant frequency will shift. Then retwist. A low feed-point resistance will require the spacer to be lowered. If your SWR meter does not indicate whether the resistance is high or low, you will have to guess which way to move the spacer.

This sounds like an arduous setup procedure but it is actually very quick and easy to do, especially where the spacer is easily accessible from the ground. With the antenna vertical it should be possible to get an SWR of very close to 1:1 on your favorite frequency. If you can't get the SWR down below 1.5:1 then suspect that something is wrong. Also, once you have the antenna in position, check the 2:1 SWR bandwidth. It should be roughly that shown in the dimension table. If it is substantially wider than this, you should suspect that losses are higher than they should be. Finally, when all appears well, find an unused frequency and apply power for a minute or so, then check that the balun is not getting hot. This is a big advantage of a ground-mounted feed point!

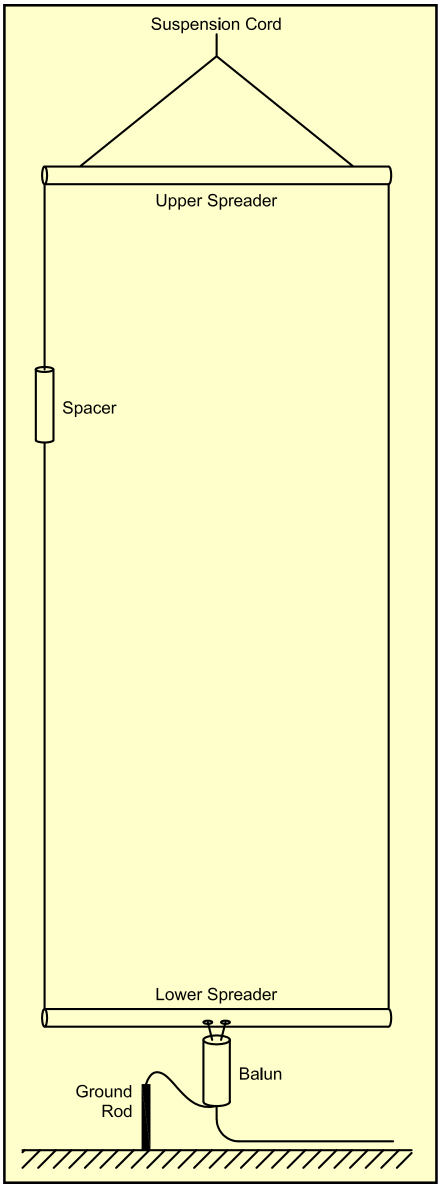

Figure 4—The antenna constructional details.

Additional Notes

It is likely that a "sloper" version will work well and it is obviously easy to support, but I have not tried it.

If you are running more than 100 W out I suggest you use air-core baluns. As pointed out earlier, ferrite-core baluns can be problematic in situations where there is considerable common-mode potential. The hysteresis losses are strongly dependent on frequency and on the flux density. For a given frequency, the hysteresis losses are proportional to somewhere between the square and the cube of the flux density. This can cause distortion and heating problems. The ferrite-cored baluns described here will loaf along at 100 W but I wouldn't recommend that you go too much above that.

The name I came up with for this antenna is the "C pole," because of its shape and because the popular "J pole" is so-named for its resemblance to the shape of that letter.

Does it Work?

The evidence I have that this is an effective antenna is part scientific and part observational. The scientific part refers to the observation that the antenna Q, as measured by the 2:1 SWR bandwidth, is as expected, and the expected Q includes the effects of identifiable loss mechanisms. The observational part is simple—it is very easy to work DX stations, even though I never run more than 100 W out. Part of that is no doubt because of my excellent location, but the antenna does play a significant role. I'm sure you can tell when you are using a good antenna system—with an effective antenna, operating is a pleasure, not a struggle. That is the way it has been with this antenna design, and if you put it together carefully I'm sure you will get the same enjoyment out of it that I have.

Brian Cake, KF2YN, was born in England and first licensed as G8AFH. He received an EE degree from City University, London. Brian is now retired after 15 years as Chief Technical Officer at LeCroy Corporation, where he was manager of the Advanced Development Group. He now lives on the Matanzas Inlet, near St Augustine, Florida where he designs and tests new antenna ideas and builds miniature live-steam locomotives. Brian can be reached at 248 Barrataria Dr, St Augustine, FL 32080; **bcake@bellsouth.net**.