Generating Circular Polarization at HF in the Real World
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My December 2015 Monthly Feature asked the question "Is circular polarization worth the effort?" Circular polarization requires a three-dimensional structure (whether it be crossed Yagis, an array that twists the elements on the boom or a helical array). This makes it more of a problem due to mechanical reasons. Also, to take full advantage of circular polarization, you need to be able to select left-hand or right-hand circular polarization depending on the prevalent ionospheric conditions. My conclusion for the question "Is circular polarization worth the effort?" was that it likely depended on your goals in Amateur Radio.

Unfortunately the two issues noted above aren't the only ones when deciding if you want to try circular polarization at HF. Brian K6STI [see Note 1] read my December 2015 Monthly Feature, and pointed out that generating circular polarization at HF in the real world isn't as easy as I led everyone to believe. This third issue is tied to putting the antenna over ground. To show the impact of ground, let's go through a progression from free space to perfect ground to average ground with a 20-Meter crossed-dipole array (commonly known as a turnstile – the two elements are orthogonal and fed 90^{o} out of phase).

Figure 1 shows the array. The center of the array (where the dipoles cross) is at 60 feet.

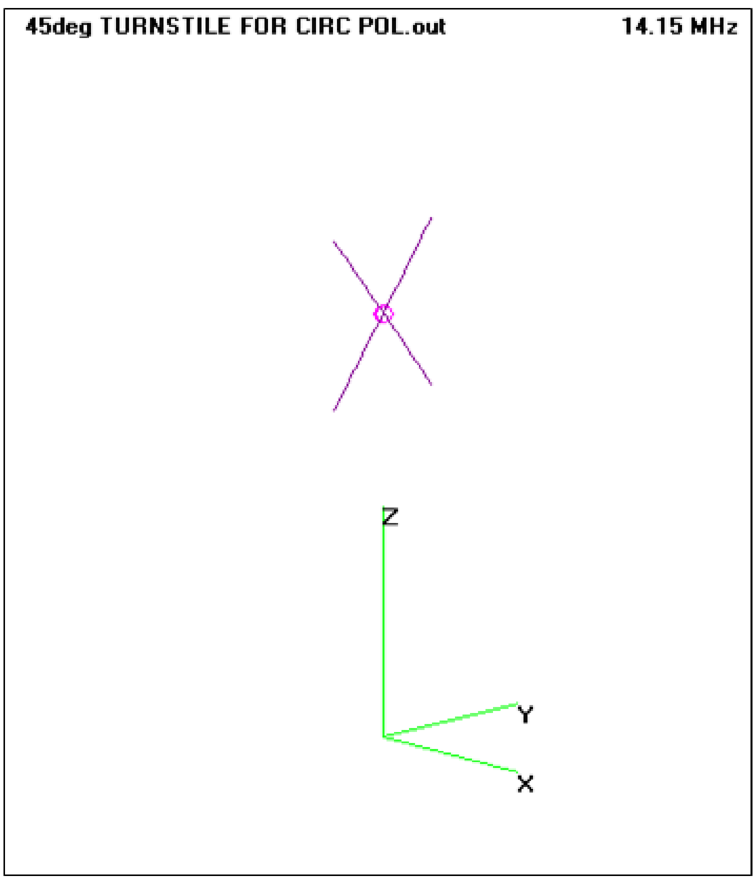

Figure 1 – Crossed-Dipole Array

Now let's look at the <u>elevation</u> pattern in <u>free space</u>. Figure 2 does this. Since we're in free space, we see the elevation pattern from above the antenna to below the antenna (from a 0° zenith angle to a ±180° zenith angle – see Note 2).

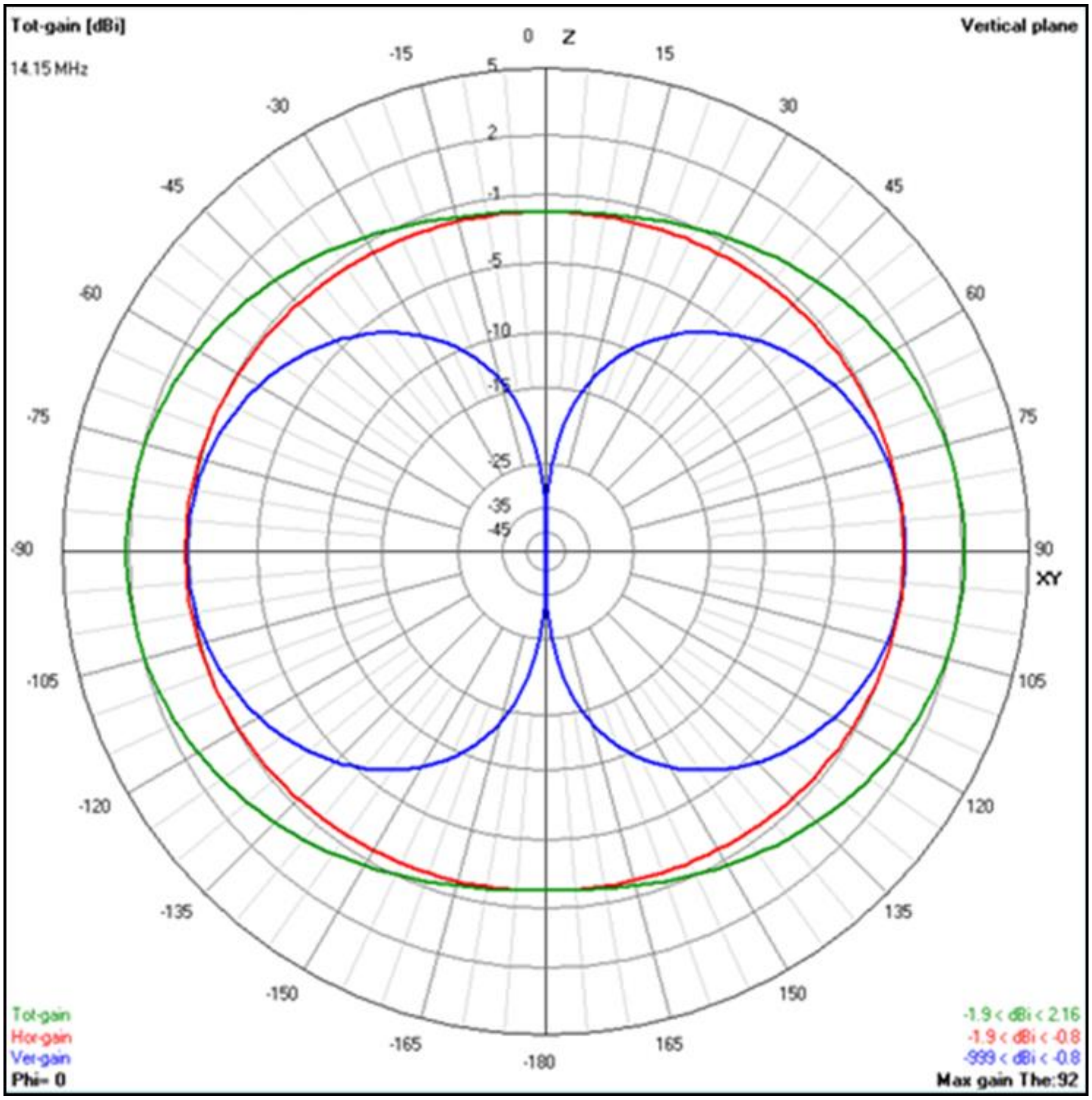

Figure 2 – Crossed-Dipole Array Elevation Pattern in Free Space

The red curve is the horizontal gain, the blue curve is the vertical gain and the green curve is the total gain when the horizontal and vertical components are added together. Note that the horizontal gain and vertical gain are equal for about +/- 15° on the nose (also known as the boresight – to the left at -90° and to the right at +90° in the figure). Having the horizontal gain and vertical gain the same on the nose is a good indication that there is circular polarization on the nose. Also note that the total gain on the nose is 3 dB higher than either the horizontal component or the vertical component.

The next step is to put the crossed-dipole array over <u>perfect ground</u> (high conductivity – like salt water) and again look at the <u>elevation</u> pattern. Figure 3 shows the result of this.

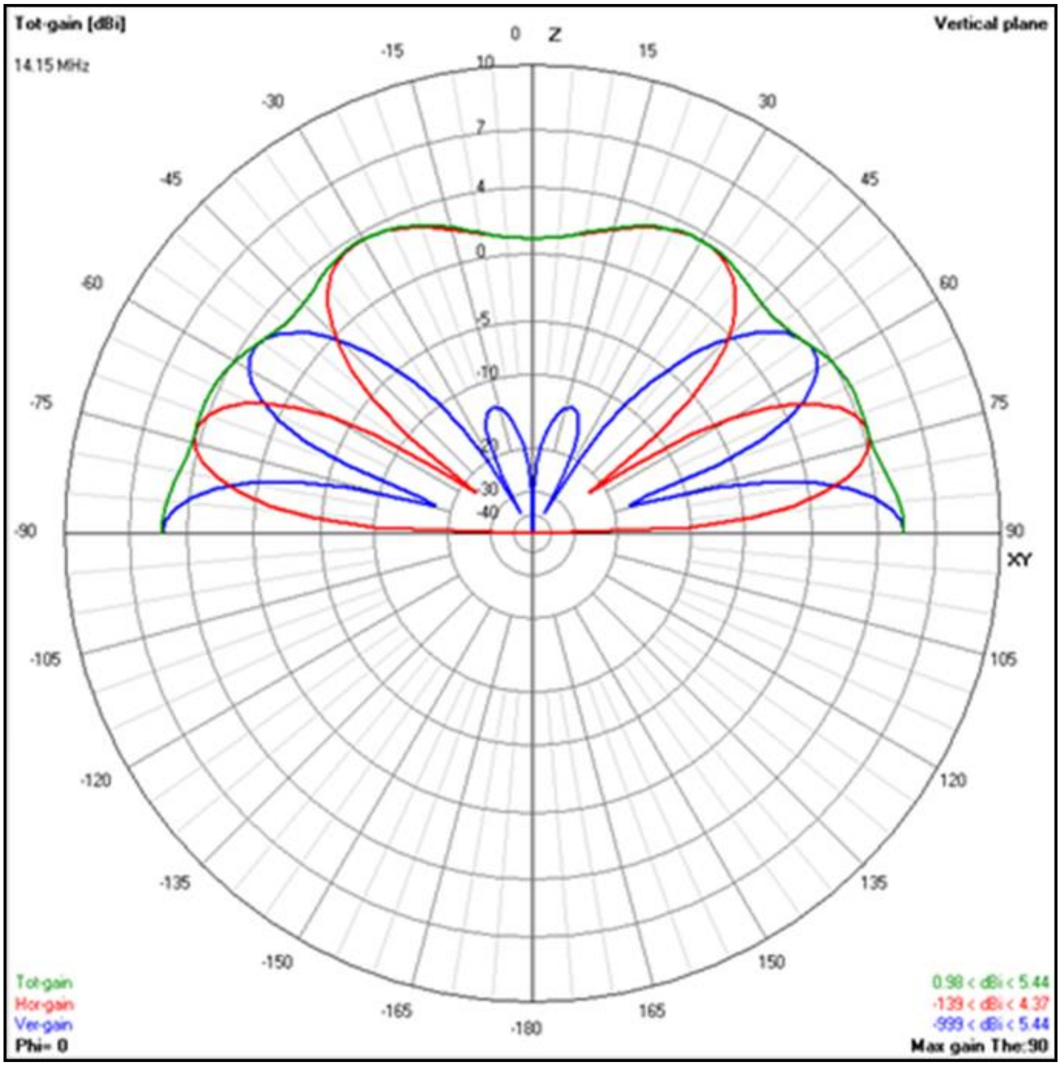

Figure 3 – Crossed-Dipole Array Elevation Pattern over Perfect Ground

In terms of early space-age vernacular, “Houston, we have a problem”. The horizontal component (red) has a null on the horizon (-90º and +90º) while the vertical component (blue) has a maximum on the horizon. The horizontal lobes do not coincide with the vertical lobes. This tells us there isn’t circular polarization from this antenna now that it is over perfect ground. Because of this, the total gain is never higher than the maximum horizontal component or the maximum vertical component.

The reason for this result is simple – the horizontal and vertical components of this crossed-dipole array react differently to perfect ground. The horizontal component is the same as a dipole over perfect ground (null on the horizon), whereas the vertical component is the same as a vertical over perfect ground (maximum on the horizon).

This result does not bode well for putting the crossed-dipole array over average ground (conductivity = .005 Siemens and dielectric constant = 13). The horizontal component will still react differently than the vertical component, but maybe not to the same extent as over perfect ground. Going through this exercise gives us Figure 4.

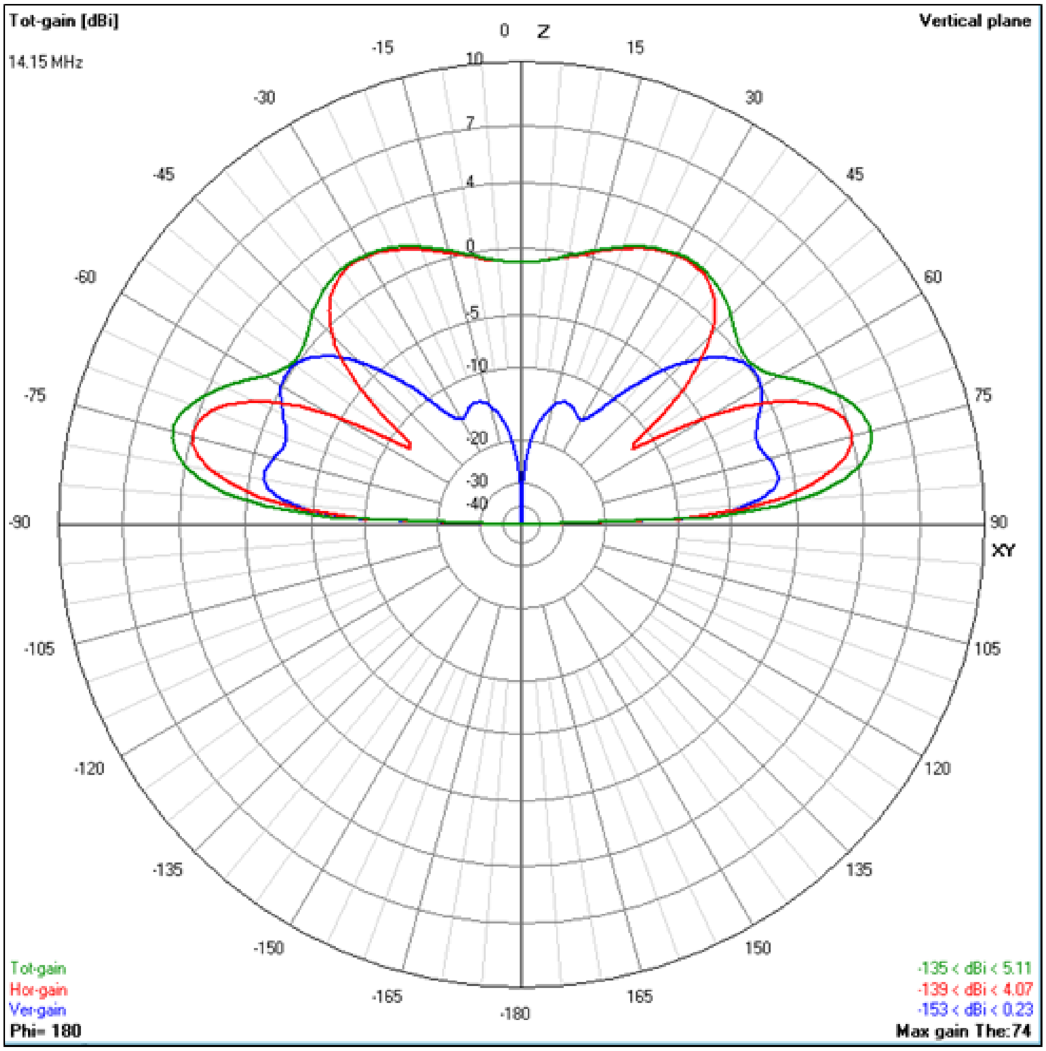

Figure 4 – Crossed-Dipole Array Elevation Pattern over Average Ground

Due to the loss of the vertical component over average ground, the lowest horizontal component lobe and the vertical component lobe are somewhat lined up. But there's still a difference in amplitude between the two components – about 6 dB at the zenith angle of 75^{o} (elevation angle of 15^{o}) in favor of the horizontal component. Note that the total gain is about 1 dB higher at the 75^{o} zenith angle

So when we put our crossed-dipole array over average ground, we don't end up with perfect circular polarization. But there still is likely to be an advantage even though the circular polarization is not perfect. I make this statement based on the articles mentioned at the top of page 3 of the December 2015 Monthly Feature that claimed circular polarization gave longer duration openings with less fading. Undoubtedly the antennas in those articles suffered a similar fate to the results seen in Figure 4 here, but still some good came out of it.

The bottom line is it is tough to create perfect circular polarization at HF due to the effects of ground (and don't forget the effects of nearby metal structures). Thus K6STI was correct to bring this to my attention. Brian also offered some solutions to this problem, and I encourage you to visit his web site at http://ham-radio.com/k6sti/. There are several circular polarization topics in the Antennas section on his home page.

Note 1 – For those of you who began antenna modeling in the mid 1990s, you may remember NEC/WIRES 2.0 from K6STI. That's the first modeling software I ever had, and I used it with an IBM PC. I still have the 3.5 inch disk.

Note 2 – The modeling in this Monthly Feature was done with 4nec2 from Arie Voors. The elevation patterns are reported in terms of zenith angles (0^o zenith angle is overhead, which is equivalent to a 90^o elevation angle).