A Rule of Thumb for Antenna Gain vs Height

Carl Luetzelschwab K9LA   November 2015

Throughout my Amateur Radio career I've learned many 'rules of thumb' that are applicable to many different aspects of our hobby. One of the earliest ones that I learned was in relation to the length of a horizontal half-wave dipole. In free space for a horizontal dipole with infinitely thin wire, the length of a half-wave is 492 divided by the frequency in MHz.

But we don't put up infinitely thin horizontal dipoles in free space. To adjust for the antenna being over real ground with a reasonable diameter wire and having insulators on each end, we use the equation 468 divided by the frequency in MHz. This should get you very close to a resonant antenna. As a side note, it's more along the lines of 480 divided by the frequency in MHz for an inverted-vee due to the angle between each side being less than 180 degrees.

Another rule of thumb tied to antennas is the one we'll focus on this month. I saw this one many, many years ago (maybe in the old 73 magazine – anyone out there remember this?). The author stated that if you double the height of a horizontal antenna, you'll get 6 dB more gain.

To investigate this rule of thumb, I modeled a horizontal dipole at one-quarter wavelength high, one-half wavelength high and one wavelength high. I did this on 14.0 MHz using average ground conditions (dielectric constant of 13 and conductivity of .005 Siemens/meter). Figure 1 shows the results of this exercise.

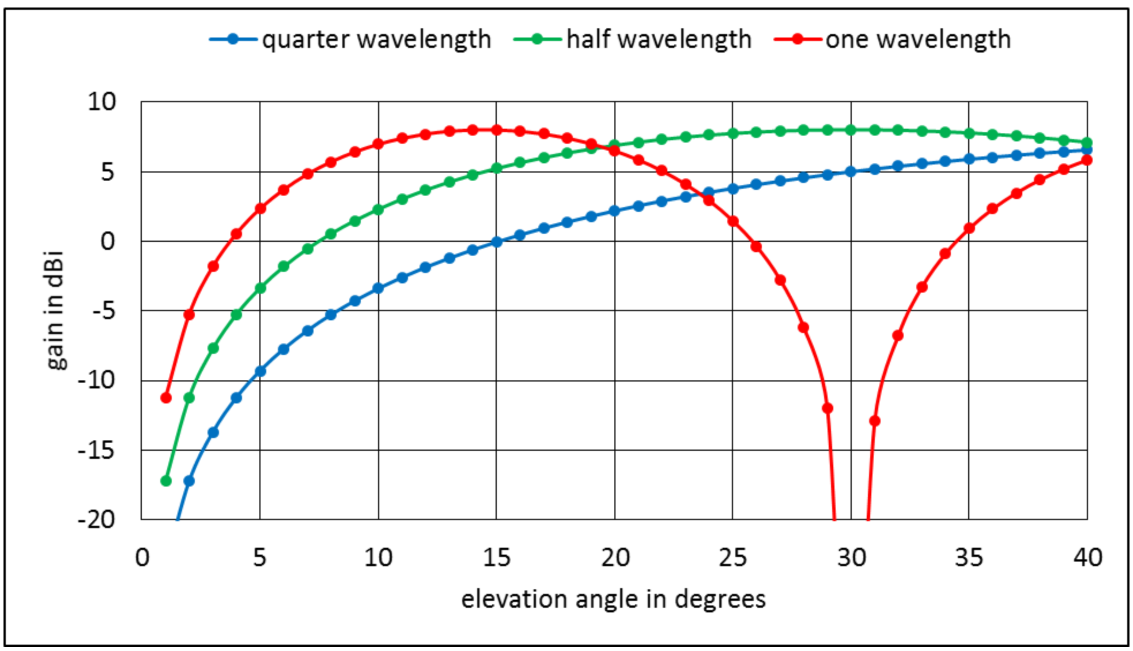

Figure 1 – Gain of Dipole at Various Heights

There should be several familiar results in Figure 1. For the dipole at one wavelength (red curve), the max gain is around an elevation angle of 14 degrees, with a null around 30 degrees. For the dipole at one-half wavelength (green curve), the max gain is around an elevation angle of 30 degrees. For the dipole at one-quarter wavelength (blue curve), the max gain occurs at a high elevation angle (off the chart).

From eyeballing Figure 1, it looks like all three curves parallel each other out to 10 degrees or so – with the difference on the order of 6 dB. To better see this, let's plot the difference (in dB) between each of the curves in Figure 1. Figure 2 does this.

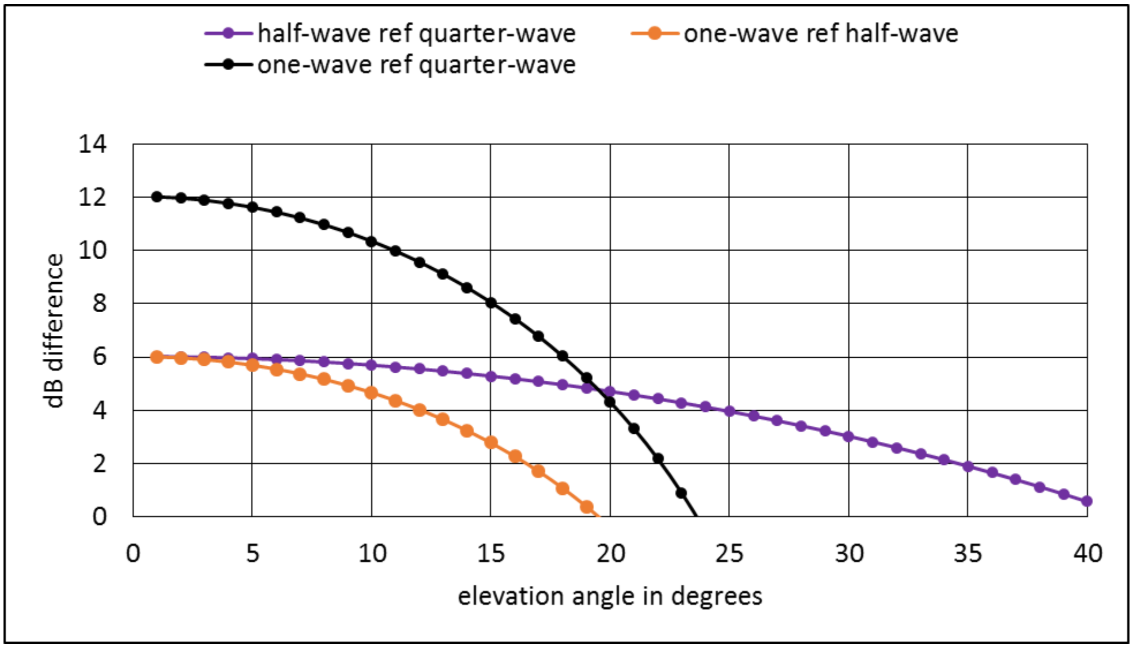

Figure 2 – Gain Differences of the Three Dipoles

The difference between the one-wavelength high dipole and the half-wavelength high dipole (orange curve) is indeed around 6 dB up to an elevation angle of 5 degrees or so. The difference between the half-wavelength high dipole and the quarter-wavelength high dipole (purple curve) is also around 6 dB – but it goes up to an elevation angle of 10 degrees or so. The difference between the one-wavelength high dipole and the quarter-wavelength high dipole (black curve) is around 12 dB up to an elevation angle of 5 degrees or so (this one makes sense since doubling the height increases gain by 6 dB, so quadrupling the height should increase gain by 12 dB).

Thus this rule of thumb should have a qualifier after it. It would be best to say something like "doubling the height increases the gain by 6 dB at very low elevation angles" A practical example of this rule of thumb would be moving your 20-Meter dipole from 17 feet high (a quarter wavelength) to 34 feet high (a half wavelength). You should see about one S-unit higher signal levels from low elevation angle signals.

A good question to ask is "not all signals arrive at very low elevation angles – is it worth the effort to double the height?" This depends on your goal. If your goal is to get on the DXCC Honor Roll, then that one S-unit would be a very big help (as a reminder, it helps on both receive and transmit). Tied to this is the fact that many DX signals come in at very low elevation angles – the DX signals you need to get on the Honor Roll.

To add a quantitative aspect to DX elevation angles, let's look at elevation angle statistics for W9 (Indianapolis) to Europe on 20-Meters. This data is on the CD in the ARRL Antenna Book. Figure 3 plots this data.

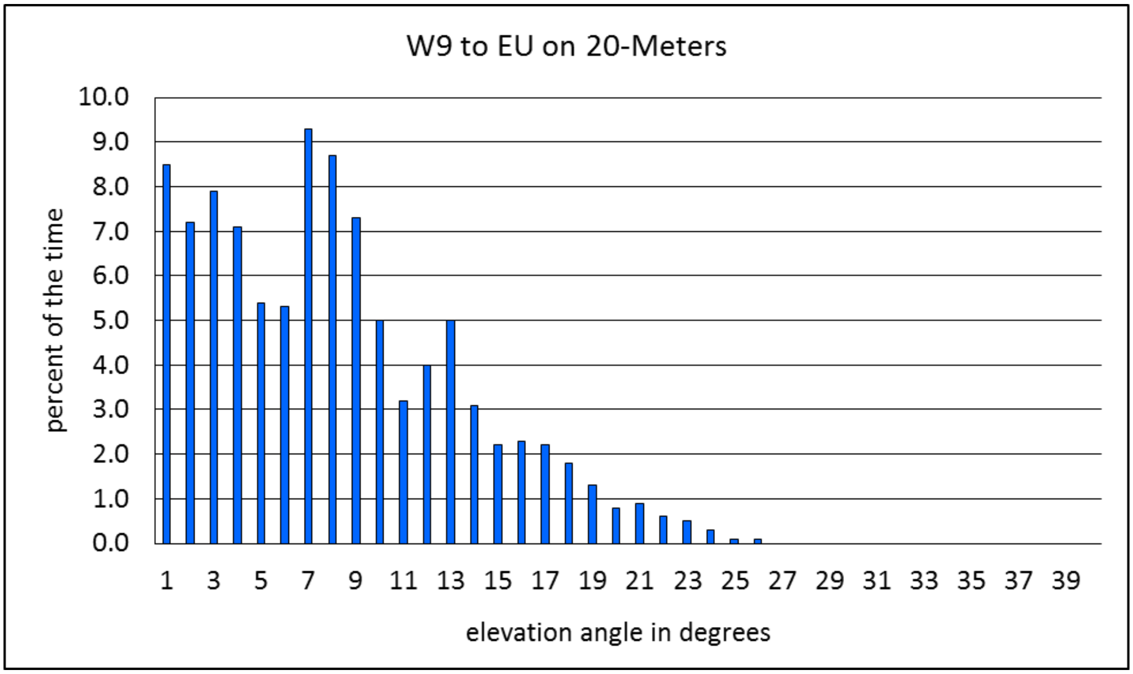

Figure 3 – Elevation Angle Statistics

At a 1 degree elevation angle, we would expect signals to come in at this angle about 8.5% of the time. Remembering that the difference between a half-wavelength high dipole and a quarter-wavelength high dipole was around 6 dB up to 10 degrees or so, we can calculate the cumulative total for elevations angles from 1 to 10 degrees. That works out to 71.7% of the time.

Thus you should see the 6 dB improvement quite a bit of the time on 20-Meter signals to Europe. We could do this for other areas of the world and other bands, and we'll come to the same conclusion – it's worth looking into doubling the height of your horizontal antenna. Although I haven't worked it out, I suspect the same advantage would generally apply to an inverted-vee. So think about raising your dipole or Yagi to help your DXing endeavors. I'm sure you'll benefit from this effort.