Propagation
WorldRadio February 2012
Carl Luetzelschwab K9LA

At What Height Should I Mount My 10-Meter Antenna? (with an addendum at the end)

In 2008, 2009, and last year (we missed 2010), a team of local Fort Wayne DXers did a Multi-Two operation from my QTH in the CQ World Wide Phone DX contest at the end of October. This last year the team consisted of KC9GGV, W9HT, W9LW, WB9NOO, KJ9R, and of course me. Our goal has always been to have fun working as much DX as possible, and 2011 provided lots of QSOs on the higher bands (15 and 10-Meters).

With Cycle 24 activity on the increase, we figured 10-Meters would be a big player in the 2011 contest. To help our efforts on this band, I bought a Hy-Gain 105CA 5-element 10-Meter monobander. KC9GGV and I put it together, and then KC9GGV, his son, my wife Vicky AE9YL, and I temporarily mounted it next to the house on three sections of tower at the grand height of 25 feet the weekend before the contest. Regardless of its low height and proximity to the house, it played extremely well. After the contest, I couldn't help but wonder how much better it will play when it's in the clear and higher.

So how high should I mount it? Keep it at 25 feet? Put it at 50 feet? Move it even higher to 100 feet? With a little knowledge of propagation, we can evaluate the best height for this 10-Meter antenna. We'll do this by applying what we know about elevation angles. First, though, let's looks at some history of this interesting and important topic.

Some of you may remember the earlier ARRL Antenna Books (from the 1960s and 1970s). They had some tabular data on elevation arrival angles on several of the bands (I believe the data included 40, 20, 15, and 10-Meters). The data was somewhat sparse, but it was the best we had at the time. This data was kind of supported by occasional measurements by the scientific community of actual arrival angles on very specific paths and frequencies.

The next important step in understanding elevation arrival angles came in Dr. James L. Lawson W2PV's (SK) book titled **Yagi Antenna Design** in 1986 (published by the American Radio Relay League). This was a seminal discussion of computer modeling of Yagi antennas, and it included a chapter on the effects of ground.

In this chapter, Dr. Lawson plotted the elevation angle versus hop distance for 1 to 6 hops assuming F_2 region propagation from a reflecting shell at 300 km (somewhat of an average between a lower F_2 region height of 250 km and an upper F_2 region height of 400 km). From this simple model of the ionosphere, Dr. Lawson concluded that to cover distances greater than 1600 km with 1 through 6 hops, elevation angles from 3 to 17 degrees were needed. Note that this was only a range of angles – no information on the distribution of angles was given.

Dr. Lawson followed this up with plots of elevation patterns of a Yagi from 0.1 wavelengths high to 3.0 wavelengths high (in mostly 0.25 wavelength steps). From all of these plots it was obvious that an antenna height of 1.5 wavelengths best covered the 3 to 17 degree elevation angle range. On 10-Meters, this would be a height of about 50 feet.

The next important step in better understanding elevation arrival angles came from Dean Straw N6BV. He ran many predictions with IONCAP from the 10 call districts to the world at three levels of solar activity for October (CQ WW DX PH), November (CQ WW DX CW), February (ARRL DX CW), and March (ARRL DX PH). The results were compiled into his book (actually it's a three-ring binder) titled **All The Right Angles** (1993, published by LTA). In addition to the range of elevation arrival angles (minimum angle and maximum angle), the occurrence rates of the angles were tabulated. This showed which elevation angle was most likely to occur, and in many cases bi-modal results (two angles with high occurrence rates) were evident.

N6BV subsequently revised this data with VOACAP (the Voice of America version of IONCAP). This data is on the CD-ROM in the new 2012 ARRL Antenna Book, which is the 22nd Edition. This data is in the HFTA (High Frequency Terrain Analysis) section. The closest city to Fort Wayne in this data is Indianapolis (about 100 miles southwest of me). Figure 1 plots this elevation angle data for six areas of the world (Europe, Japan, Africa, Southeast Asia, Oceania, and South America) and the USA.

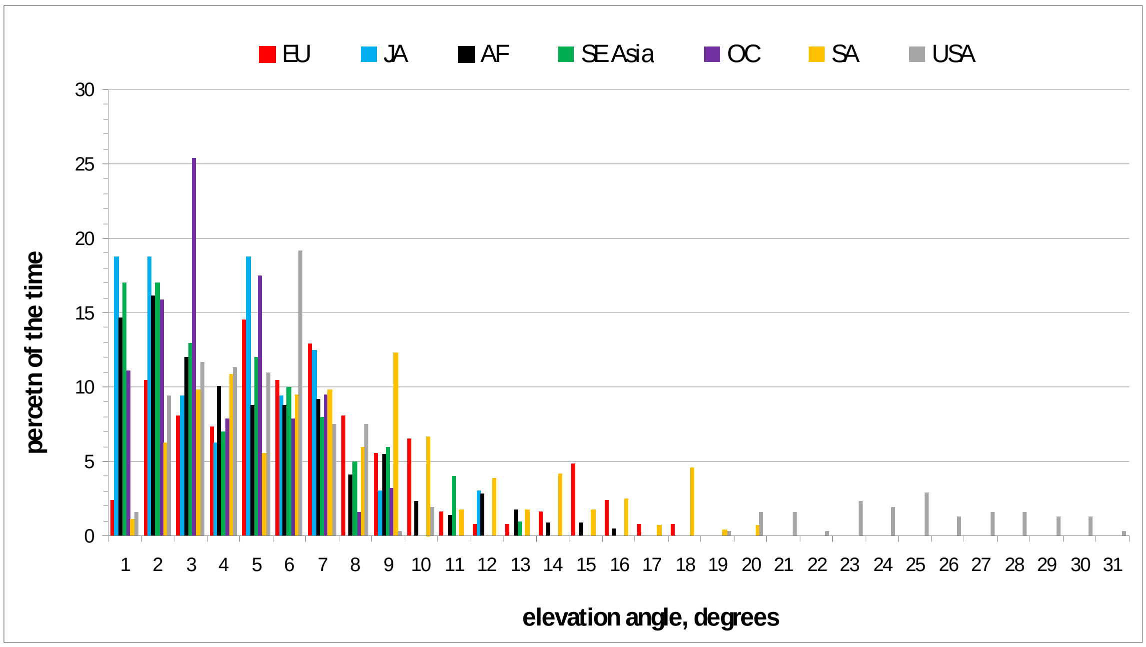

Figure 1 – Elevation Angles for Indianapolis to
6 Areas of the World and the USA on 10-Meters

The horizontal axis in Figure 1 is elevation angle from 1 to 31 degrees. The vertical axis is the percent occurrence. For example, from Indianapolis to Oceania the elevation angle of 3 degrees occurs about 25% of time.

Overall what Figure 1 shows is that indeed elevation angles up to 17 degrees, as suggested by Dr. Lawson, are important for our DXing efforts. But note that elevation angles less than 3 degrees (1 degree and 2 degrees) are extremely important, too. Thus Dr. Lawson's analysis may not have stressed the extremely low angles enough. Also note that for the closer-in USA stations, higher angles are desired – all the way out to 31 degrees – which makes sense for shorter distances.

Now let's look at the elevation patterns of a 10-Meter Yagi at several heights. Figure 2 does this, with the elevation angles of the six worldwide areas and the USA combined into one set of data.

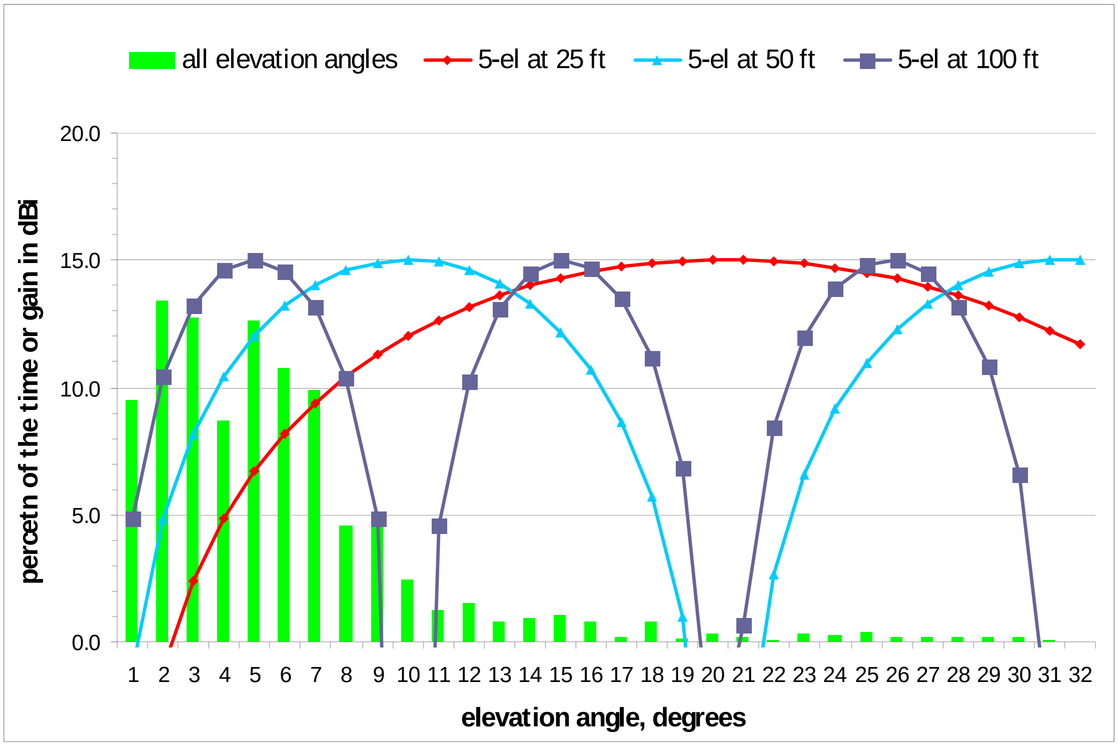

Figure 2 – Yagi Elevation Patterns Superimposed on Elevation Angle Data

The horizontal axis is again elevation angle. The vertical axis does double duty – it's the elevation angle occurrence rate (in percent) and it's also the gain in dBi of a 5-element 10-Meter Yagi over ground. You're probably more familiar with antenna elevation pattern plots in polar format – the plots in Figure 2 are in rectangular format to better mesh with the elevation angle data.

The Yagi at 25 feet (red curve) certainly covers most of the angles, but it falls off at many of the important lower angles for DXing.

The Yagi at 50 feet (blue curve) covers the important 3 to 17 degrees very well, but gives up gain at the two extremely low elevation angles. And it has a null from about 19 to 22 degrees, which is mostly USA coverage (refer back to Figure 1 to see this).

The Yagi at 100 feet (purple curve) covers the low angles very well, including 1 and 2 degrees. But it has two nulls – one from about 9 to 11 degrees (which is important for both DXing and USA coverage) and the other from about 19 to 21 degrees (which is important for USA coverage).

If you could only put up one antenna, what height would be best? I believe the 50 foot high Yagi would be the best all-around player, which agrees with Dr. Lawson's conclusion. This is what I plan to do with my 5-element monbander.

This data also brings us to a major conclusion – that a single antenna doesn't cover all the angles. The ideal solution would be to put up all three, i.e., a three-high stack. And with proper cabling and switching, you could select either or all three depending on conditions, and be assured that you're covering all the angles.

Addendum – October 2014

As can be seen in the header on the first page of this article, the original version appeared in the February 2012 issue of WorldRadio. The basic question that was asked was "what is the best height to mount your 10-Meter antenna?" The choices were 25 feet, 50 feet and 100 feet. I assumed these heights were in the range of the capabilities of most people. My conclusion was 50 feet was the best height.

In October 2014 I received an e-mail from Jim Wolf KR9U, and he commented that his experience with a 10-Meter antenna on a 50-foot tower and with the another identical 10-Meter antenna on a 100-feet tower was that the high antenna was better most every time.

In another e-mail, John Goller K9UWA echoed KR9U's comment that most of the time his highest antennas were best – but K9UWA's comparison was between a four-high stack of 10-Meter antennas with the highest at 89 feet, a single 10-Meter antenna at 160 feet and a two-high stack of 10-Meter antennas at 116 feet and 160 feet. Although K9UWA's comments are valid, they are out of the range of heights that I considered in the original article.

My original conclusion that the 50-foot high antenna was best was based on the 50-foot high antenna having only one null in its elevation pattern, whereas the 100-foot high antenna has two nulls – one at elevation angles important for DXing and lower-angle domestic QSOs, and one at elevation angles important for higher-angle domestic QSOs. I acknowledged that the 50-foot high antenna would give up gain to the 100-foot high antenna at the extremely low elevation angles, but I considered that not as important as nulls in the pattern.

So why does KR9U see the 100-foot high antenna as the better one most of the time? There could be two reasons for this. First, maybe he hasn't observed over the full time period of the elevation angle statistics. The elevation angles presented are for all times when the 10-Meter band is open throughout the day, for all the months, for all solar conditions from solar minimum to a big solar maximum, and to DX (low angles) and domestic locations (low and high angles).

Another way to look at this is to take the data from my Figure 2 and work out the percentage of the time when the 50-foot antenna is better in terms of signal strength and the percentage of the time when the 100-foot antenna is better. This works out to the 50-foot high antenna being better about 15% of the time, and the 100-foot high antenna being better about 85% of the time. Thus the theoretical results from Figure 2 generally fall in line with KR9U's observations. The question here is "did KR9U observe all the possibilities?"

Second, and tied into the theoretical results, is the question of whether the elevation patterns are accurate – specifically in the nulls. Could irregularities in the ground composition and ground flatness (not accounted for in the antenna model) fill in the nulls so that they aren't as far down as indicated? In other words, perhaps the 100-foot high antenna doesn't give up as much in the range of elevation angles around 10 degrees and 20 degrees.

An issue not addressed in the original article was modes other than F2 propagation. What about ground wave? What about sporadic E? What about scatter? It very well could be that the 100-foot high antenna is best under these conditions, and thus would slant the decision more to the 100-foot high antenna.

Finally, I didn't discuss property requirements or financial issues in my conclusion. A 100-foot tower would likely require guying, whereas a properly constructed 50-foot high tower wouldn't (my 5-element 10-Meter monobander is on a self-supporting 50-foot aluminum tower). Going to 100 feet makes the tower footprint larger, which requires more property. Also, just going from 50 feet to 100 feet is going to incur more tower expense.

I think the best conclusion after considering everything is to say that if you're property limited and/or finance limited, the 50-foot high antenna is the way to go, and will give a good account of itself. But if you can put up a 100-foot tower, go for it – and mount another 10-Meter antenna at 50 feet on the tower with proper phasing to select either antenna or both antennas. Or do what I said at the end of the original article – put three antennas on the 100-foot tower with proper phasing.