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Carl Luetzelschwab K9LA   k9la@arrl.net

Measuring the Elevation Angle of Arriving Signals

Have you ever wanted to do more than just sit in front of your radio and make contacts? Maybe you've had the desire to contribute to Amateur Radio knowledge. In that vein, there are many ways to contribute, and this month's column discusses one such way. All you need are two horizontal antennas – one up relatively high and one down low. And what we'll measure is the elevation angle of arriving signals.

We should know that the elevation pattern of a horizontal antenna is mainly determined by its height above ground (there is a very small effect from the gain of the antenna). For example, my 10-Meter monobander is at 55 feet (see the February 2012 column for details), and we would expect its lowest lobe to be centered on a fairly low elevation angle since 55 feet high is 1.5 wavelengths on 10-Meters.

As for the other antenna, I put up a 10-Meter dipole at only 4 feet. We should expect this antenna to have a single lobe centered on a relatively high elevation angle. The elevation pattern of both of these antennas is shown in Figure 1.

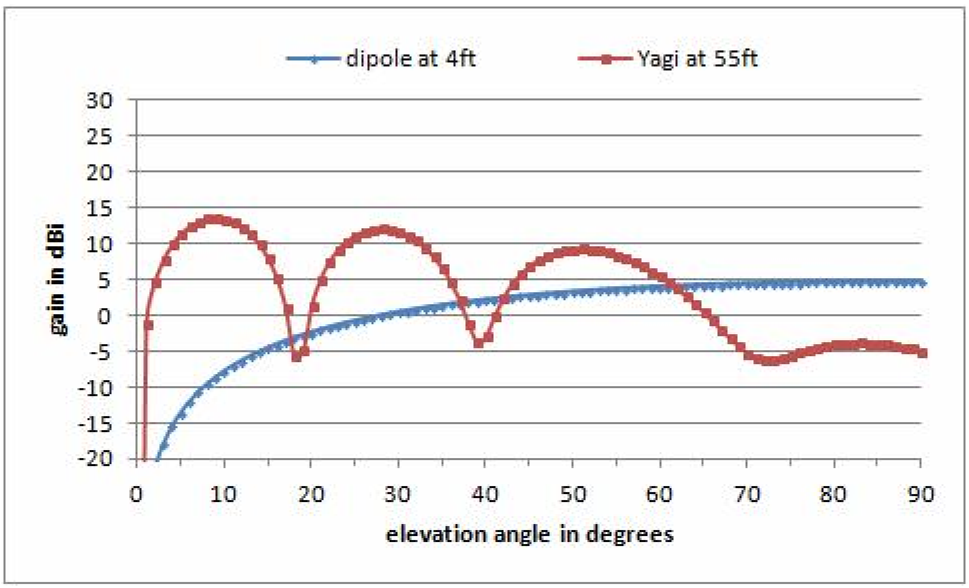

Figure 1 – Elevation pattern of the 10-Meter antennas

Indeed, our expectations are met. The high antenna has its lowest lobe centered at 9 degrees, with three more lobes of lesser peak gain. The low antenna has its peak in radiation mostly straight up (70 – 90 degrees).

The data presented in Figure 1 is interesting, but it doesn't directly help us determine the elevation angle of the arriving signal. Let's present the data in a different way – we'll subtract the gain of the low antenna from the gain of the high antenna. Figure 2 does this.

Figure 2 – Gain difference between high antenna and low antenna

Now you should see where this is going. All you have to do is note the S-meter reading on the high antenna, note the S-meter reading on low antenna, and determine the difference. Then you can determine the arriving elevation angle using Figure 2. Table 1 presents several of my results using these antennas and this method.

date	time (UTC)	station	55ft S-meter	4ft S-meter	difference (dB)	angle	comment
5-Jan-13	1548	VO1CAL	S9	S5	22	9	
	1750	A65BP	S4	S0	21	10	long path
	1820	K6RNK	S7	S3	25	5	
6-Jan-13	1334	IK6DTB	S3	nothing	-----	-----	
	1437	PA7MM	S7	S3	25	5	
	1442	G4ELJ	S5	S1	24	7	
	1445	EA8YV	S5	S1	24	7	
	1610	A45XR	S3	nothing	-----	-----	long path
12-Jan-13	1406	LA7GNA	S7	S3	25	5	
13-Jan-13	1340	OE6MBG	S5	S1	24	7	
	1347	DK2EE	S6	S3	20	11	
14-Jan-13	2250	VK2LAW	S5	S2	22	9	
17-Jan-13	1943	EA8YB	S9+5	S6	22	9	
	1944	VE1AWA	S9+5	S6	22	9	
	1947	RI1FJ	S5	S2	22	9	
	1958	ZL1BYZ	S6	S3	20	11	
20-Jan-13	1511	OE2013S	S6	S3	20	11	
	1513	G0FWX	S6	S3	20	11	
9-Feb-13	1552	N6WJN	S9+5	S6	22	9	

Table 1 – K9LA results

Some conclusions from my data include a minimum signal strength on the high antenna that allows the signal to be heard on the low antenna (about S3 for my antennas and noise environment) and some very low elevation angles. In general VOACAP predicts elevation angles in the range of my data, and actual measurements of arriving elevation angles with more sophisticated set-ups (which unfortunately are somewhat few and far between) tend to confirm the VOACAP predictions.

As in all endeavors of this nature, you have to control the experiment. In other words, you must know where there are problems that may affect your data and thus your conclusions. In this experiment there are a number of caveats.

First, calibrate your S-meter in terms of an S-meter reading versus signal power in dBm. Do it on the pertinent band, and use a commercial signal generator or a homebrew oscillator with a known output power in conjunction with a step attenuator (the latter is what I used). What you'll discover is that your S-meter is not always 6 dB per S-unit (and old Collins Radio standard that is not strictly adhered to anymore) and that at low signal levels an S-unit may be a difference of only a couple dB. See Table 2 for the S-meter results of my OMNI VI Plus.

OMNI VI Plus - 10m - ATTN OFF	
S-meter	**dBm**
S9+20	-45
S9+10	-57
S9+5	-61
S9	-66
S8	-72
S7	-78
S6	-83
S5	-88
S4	-93
S3	-103
S2	-110
S1	-112
S0	-114

Table 2 – Calibration of the S-meter in my OMNI VI Plus

Second, make sure the antennas are tip-to-tip for minimal interaction. The wire of my low dipole runs southeast to northwest and is about 50 feet northwest of the Yagi. Thus when my high antenna is pointed to the northeast (Europe) or to the southwest (VK/ZL), the dipole is indeed tip-to-tip for minimal interaction.

Third, how well your ground matches what you assumed in your antenna modeling program is important – especially at the very low elevation angles and in the nulls in the high antenna elevation pattern. This caveat is likely the limiting factor in the accuracy in determining the elevation angle. If your terrain is flat and the soil conditions are homogeneous, your modeled patterns should be reasonably accurate.

Fourth, realize that there is ambiguity in Figure 2 from about 15 to 65 degrees for my antennas. For example, if the strength on the high antenna is 12 dB more than on the low antenna, then the arriving elevation angle could be 15 degrees or 27 degrees. Another example is the case (the worse case, in fact) where the strength is the same on both antennas – the elevation angle could be 17.5 degrees, 19.5 degrees, 37 degrees, 42 degrees, or 61.5 degrees! At the lower elevation angles and at the very high elevation angles, you should be reasonably confident in determining the unique elevation angle.

As for practical issues, you’ll have to learn to eyeball an average S-meter reading as QSB will undoubtedly be present – try your fast AGC and your slow AGC to decide how best to do this. And this experiment is likely limited to 20-Meters and above for most of us due to getting the high antenna up high enough.

So there you go – here’s a relatively simple experiment to increase your knowledge of arriving elevation angles. Doing something like this would also be a great presentation at your local club meeting or at a local hamfest. Have fun setting up, taking data, and making conclusions – but mind the caveats!