Antenna Interaction

Carl Luetzelschwab K9LA September 2016

This month's feature deviates from the normal solar or propagation topic. It has to do with antennas – which certainly figure into the propagation aspect. I hope you enjoy it, and I hope you learn something, too.

Many, many years ago there was an article in one of our Amateur Radio publications. I don't remember which magazine it was in, nor do I remember the author. What I remember is the author was talking about antennas that were close to each other. The author said that if the SWR of antenna A wasn't affected by placing antenna B near it, then there was no interaction between antennas A and B. At the time that sounded plausible to me.

A couple years after we moved to Fort Wayne in 1988, Jim KR9U was interested in checking the gain flatness of his TH6 tri-bander on 10-Meters. At the time I had a Cushcraft 4-element 10-Meter monobander at 72 feet. Its gain performance was pretty flat across the band, so we figured it would be good a good reference antenna with which to assess the TH6.

When we started taking measurements, things went south pretty quick. We saw a very significant decrease in the TH6 gain in the middle of the band. That didn't make sense at all. If anything, we had figured the TH6 gain would be highest in the middle of the band, and would roll off at the band edges.

We scratched our heads a bit over this. Then I noticed that I had a 3-element 10-Meter monobander lying on the ground in front of my tower. And it was pointed toward KR9U. I turned it 90^{o} (while it was still lying on the ground) and the dip in TH6 gain cleared up.

Well, let me tell you – this got me thinking about that long ago article. Maybe I was a bit hasty in agreeing with the author's statement. So let's take a look at this. We'll do it with antenna modeling. Specifically I'll use the 4nec2 software from Arie Voors, which is available for free at www.qsl.net/4nec2.

What I'll do is model a reference half-wave dipole on 20-Meters. I'll put it up at 60 feet over average ground. After taking baseline data, I'll put another half-wave dipole in front of it (and parallel to it) at the same height. I'll move it from very close to the reference dipole to very far away from the reference dipole while monitoring the reference dipole's feed point impedance and SWR, the maximum gain and the patterns (both azimuth and elevation).

The results of this exercise are shown in Figures 1 and 2. Figure 1 is how the SWR varied, while Figure 2 is how the maximum gain varied. Note that each plot also has the reference dipole performance when it is all by itself (the dots at zero distance).

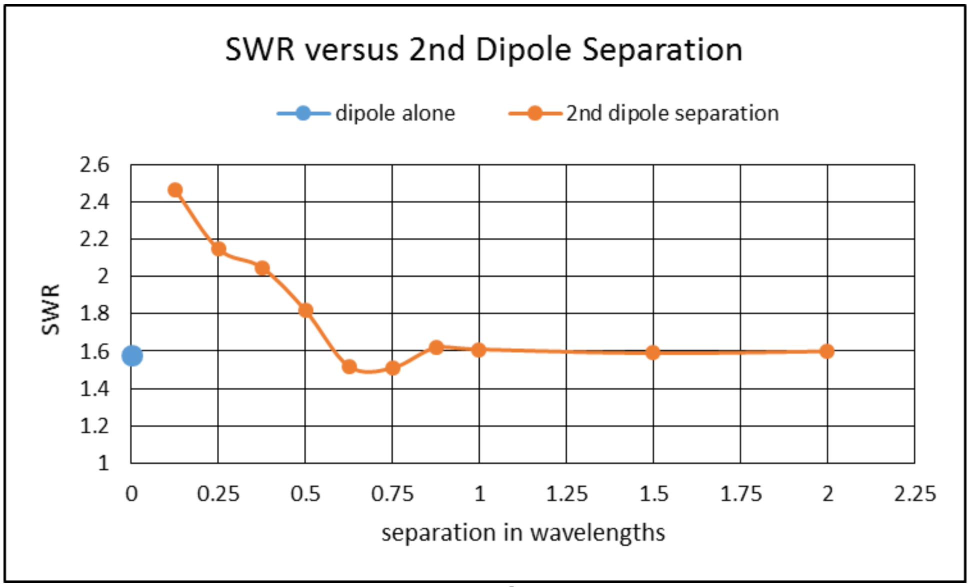


Figure 1 – SWR vs 2nd dipole separation

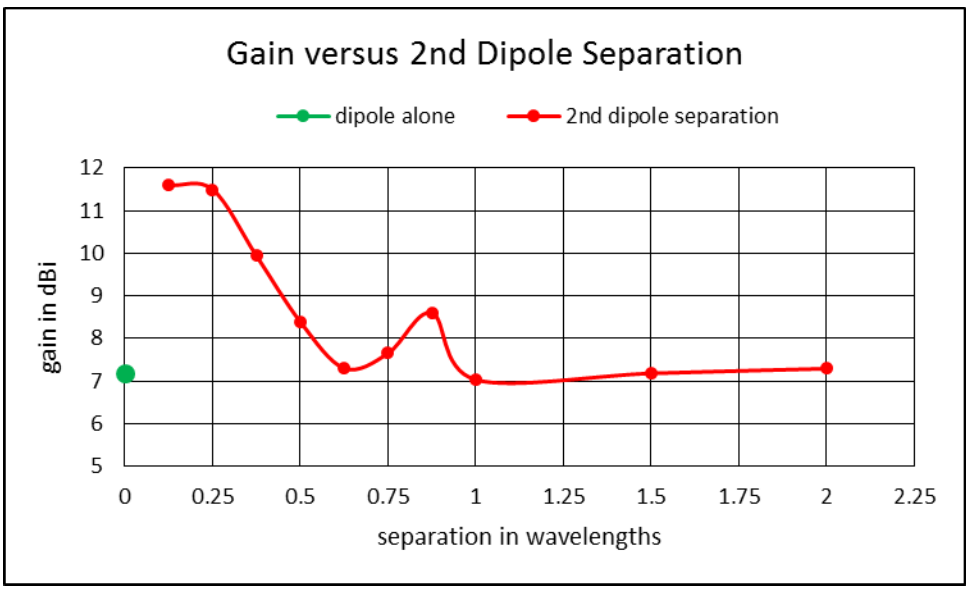
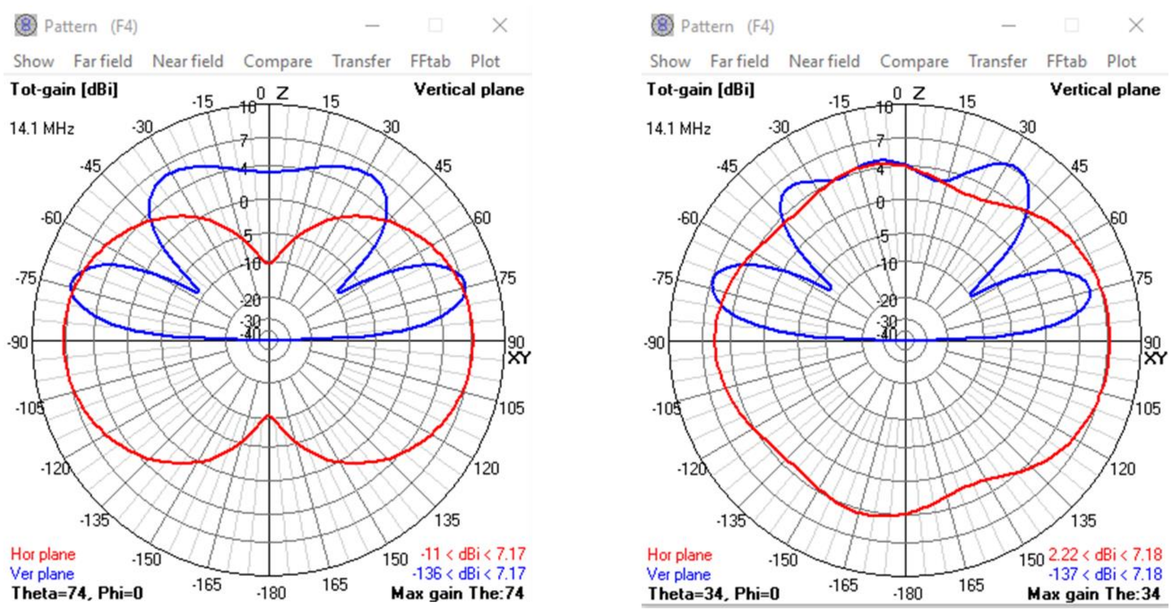


Figure 2 – Gain vs 2nd dipole separation

The SWR of the reference dipole alone is 1.58:1. When the second dipole is only 1/8 wavelength away from the reference dipole, the SWR increases to 2.47:1. As the separation increases, the SWR eventually approaches the dipole-alone value when the separation is greater than 1 wavelength.

Similarly, the maximum gain of the reference dipole alone is 7.17 dBi. When the second dipole is only 1/8 wavelength away from the reference dipole, the maximum gain increases to 11.6 dBi (we essentially now have a 2-element Yagi). As the separation increases, the maximum gain eventually approaches the dipole-alone value when the separation is greater than 1 wavelength.

What this tells us is that the SWR and maximum gain of the reference antenna aren't affected very much when the second dipole is more than 1 wavelength away. So is the long-ago author correct? Before making our final decision, let's look at the azimuth and elevation patterns. Figure 3 compares the reference dipole alone (left) to when the second dipole is 1.5 wavelengths away (right). The red curves are the azimuth patterns and the blue curves are the elevation patterns.



dipole alone | 2nd dipole 1.5 wavelengths away

Figure 3 – Patterns

Regardless of the SWR and maximum gain results, the patterns show distortion when the second dipole is 1.5 wavelengths away – especially the azimuth pattern. So my conclusion now is that the SWR does not tell you that there is no interaction. This pattern distortion will carry forward to Yagi antennas, too. If you're really interested in understanding Yagi pattern distortion with other Yagi antennas close by, I highly recommend reading Eric K3NA's 8-part series in NCJ (the National Contest Journal). The issues with his articles are Jul/Aug 2003, Sep/Oct 2003, Nov/Dec 2003, Jan/Feb 2004, Mar/Apr 2004, Sep/Oct 2004, Jul/Aug 2005 and Sep/Oct 2005. If you have many antennas on a single tower (or on towers close by), this series would be a good read.

What about the length of the second dipole? How does that impact SWR, maximum gain and patterns? Do we have to worry about any length – or just half-wavelengths? These are easy questions to answer with antenna modeling.

I placed a second dipole 1/8 of a wavelength in front of (and again parallel to) the reference dipole (one of the separations that gave the most interaction), and varied the second dipole length from short (1/16 wavelength long) to long (1.25 wavelengths long). The SWR and maximum gain results are plotted in Figures 4 and 5, respectively.

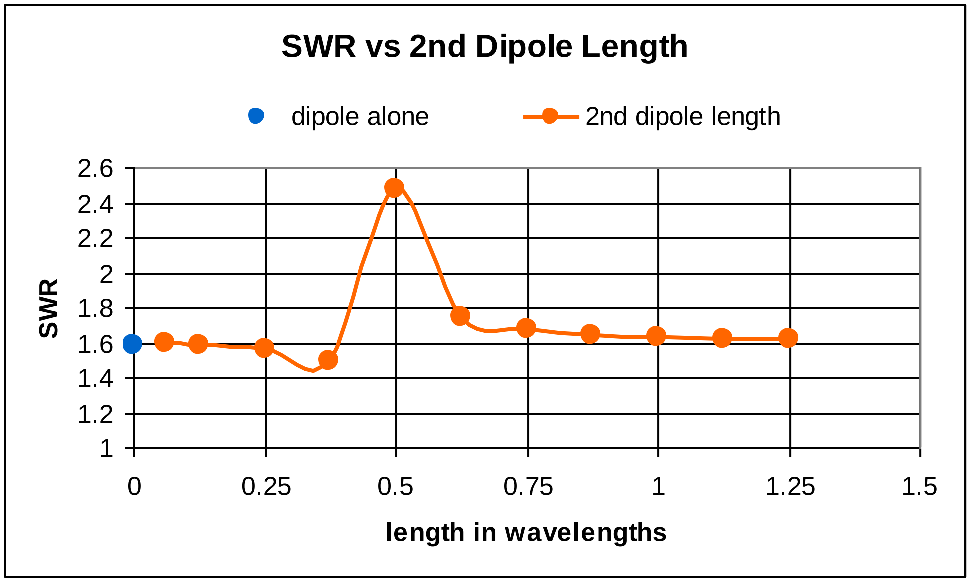


Figure 4 – SWR vs 2nd dipole length

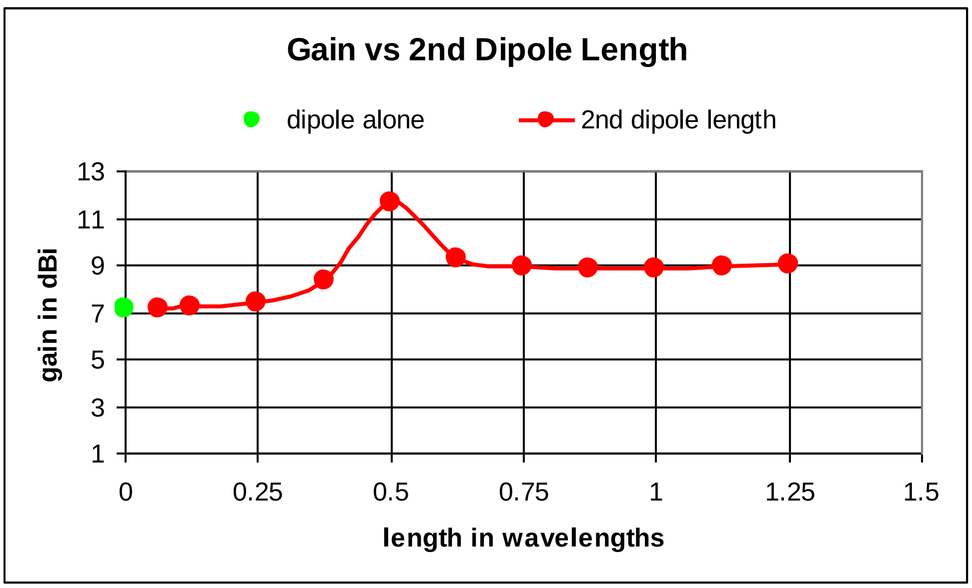


Figure 5 – Gain vs 2nd dipole length

When the second dipole is 1/8 of a wavelength away, the only length that impacts SWR and maximum gain [*note 1*] is around a half wavelength. This makes sense, as this is the underlying concept for Yagi antennas – parasitic elements slightly longer than the half-wave driven element (reflectors) and slightly shorter than the half-wave driven element (directors) give us the typical Yagi patterns.

Before closing, let's take a look at two other configurations:

1) The second dipole in front of the reference dipole is not parallel to the reference dipole – it is 90^{o} to it (simulating what happened when I turned the 3-element Yagi by 90^{o} in the TH6 measurements with KR9U).
2) The second dipole is next to the reference dipole – in other words, they are tip-to-tip.

These two configurations are shown in Figure 6.

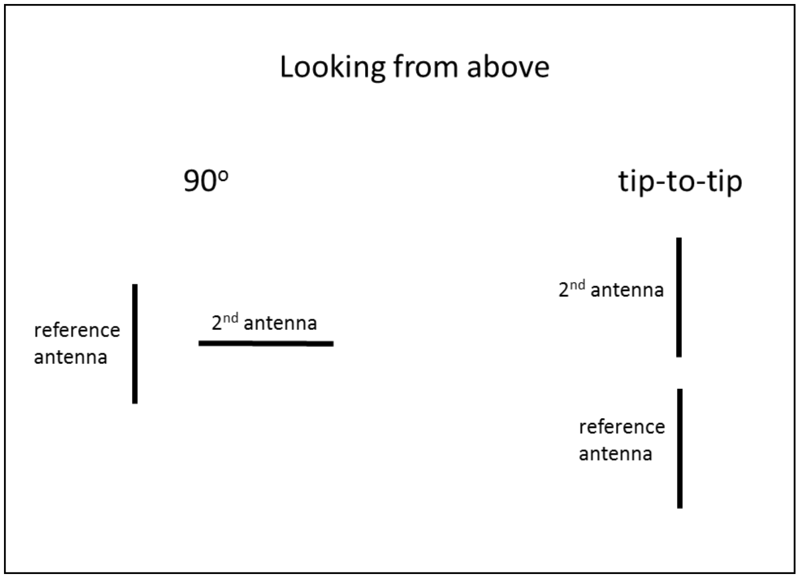


Figure 6 – Other configurations

The modeling results indicate that there is no interaction between the antennas in either of these configurations. This is why the TH6 measurements cleared up when I turned the 3-element Yagi that was lying on the ground by 90^{o}. The tip-to-tip results tell us the proper way to compare two Yagis (or dipoles) is when they are tip-to-tip. If they aren't tip-to-tip, there will be pattern distortion which will not give you the true results.

In summary, two antennas will interact even though the SWR doesn't show any change with the second antenna in place. And the other antenna has to be around a half-wavelength at the operating frequency of the reference antenna to cause significant interaction.

Note 1 – It's obvious from Figure 5 that the gain does not settle back down to the "dipole alone" value when the 2nd dipole is longer than a half wave. What we are seeing here is the residual effects of a reflecting plane in the vicinity of an antenna.