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Enhancing the Stacked Yagi by Adding Z-Axis Parasitic Elements

This article looks at the positive impact that additional parasitic elements can add to a stack of Yagis, both monoband and multiband, along with the optimization routes to take, and how I came to experiment in this area in the first place. Within this discussion, HF Yagi stacks will be covered briefly. There is good reason for this, as this will help the reader understand how this experimentation in VHF came to be.

Several years ago, I moved from VHF/UHF to HF Yagi design for commercial reasons. One of the big markets in this area is the multiband, single feed point Yagi, and this led to the development of my XR6, a 3.5-meter long HF Yagi covering 20 through 6. One common questions about this very popular Yagi was, "What is the recommended stacking distance?"

A multiband Yagi is always going to be a compromise over a monoband Yagi, and so too would any stacking distances. What would be ideal on one band would be a compromise on the others. This was a difficult concept for most customers to accept, however. They pointed out that other companies provide a recommended stacking distance for their equivalent designs, even after I had explained the associated issues that would remain with any similar design.

This started me thinking outside of the box and experimenting with the stacking distances for two or more of these multiband Yagis and to establish the pros and cons.

One requirement I had was to provide the ideal stacking distance for my new XR3-NV, tribander with a 9-meter boom. In most instances, a stack like this would be positioned at the ideal distances for 15, with 10 meters over-stacked and 20 meters under-stacked. The "ideal" would be to stack at the optimal 20-meter stacking point, with 15 and 10 benefiting from more gain due to the wider spacing. There are two byproducts of doing this, however. The first is large, high-angle, forward-facing lobes in the elevation plane — apparently not considered an issue with HF contesters — and the second is loss of front-to-back ratio (F/B). In most cases, severe over-stacking results in performance that's a lot closer to that of a rotating dipole.

Adding more Yagis closer together does not work. We have seen this in experiments in the past, with very little benefit in terms of gain seen and often with F/B still negatively affected. My first idea was to remove the 20-meter elements from the XR3-NV and re-optimize the 15- and 10-meter elements, effectively putting a form of a hybrid two-band Yagi between the tribanders. To my surprise, however, the performance on 15 and 10 did not get better, with the patterns clearly still reacting as though severely under-stacked. How about trying just early elements — specifically, reflectors — as a start?

This made a huge impact. Not only was I able to achieve decent F/B in the two "subbands" (15 and 10), but performance (when optimized) increased by more than their theoretical 3 dB maximum for a stacked pair. This result also meant that the 20-meter spacing no longer needed to be at minimum levels but closer to the ideal spacing for the 20-meter section with an increase being seen in gain on the sub bands.

After many hours of experimenting, I was able to establish enhancements that could also be achieved from the addition of a "dummy" driven element or first directors in the sub array as well, although this was heavily dependent on the extent of the over-stack of the array in question.

Figure 1 is an *EZNEC* layout of the elements of 2 × XR3-NVs with a single sub-array placed between them. In the element layout diagram, the sub-array can be seen to have a single reflector for 15 and a reflector and additional director for 10. This combination produced the best results at the spacing needed with these 2 × XR3-NVs for this customer.

This may not be the ideal or best sub-array in every instance. Individual optimization would be needed in each case. But it does mean a good result can be achieved, no matter the stacking requirements for a given installation, on the basis that the ham often is limited in the spacing for a given stacked array by tower size, other stacks, and/or guy lines. This scenario allows for an ideal sub-array to be designed/optimized to suit any installation.

What are the results? High-angle forward lobes still exist on the sub-bands with the sub-array (see Figure 2), but both gain and F/B ratio are increased on these bands; F/B increased from around 10 dB to well above 20 dB.

To give an idea as to the individual vari-

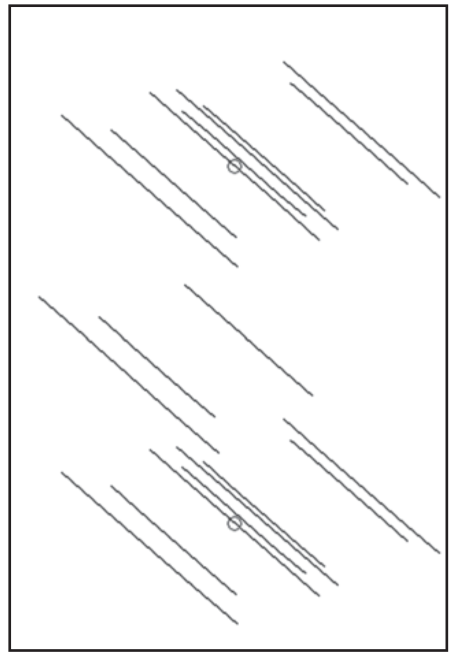

Figure 1 — 2 × triband XR3-NVs with sub-array, providing performance enhancements on 15 and 10 meters.

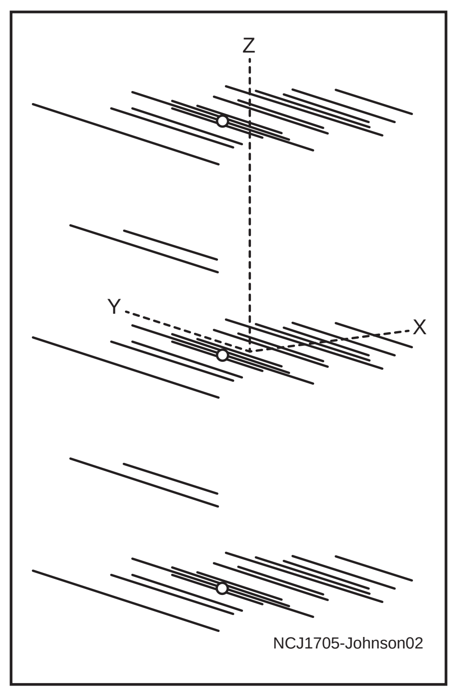

Figure 2 — Three stack of InnovAntennas/G0KSC XR3-NV triband Yagis with sub-reflector arrays.

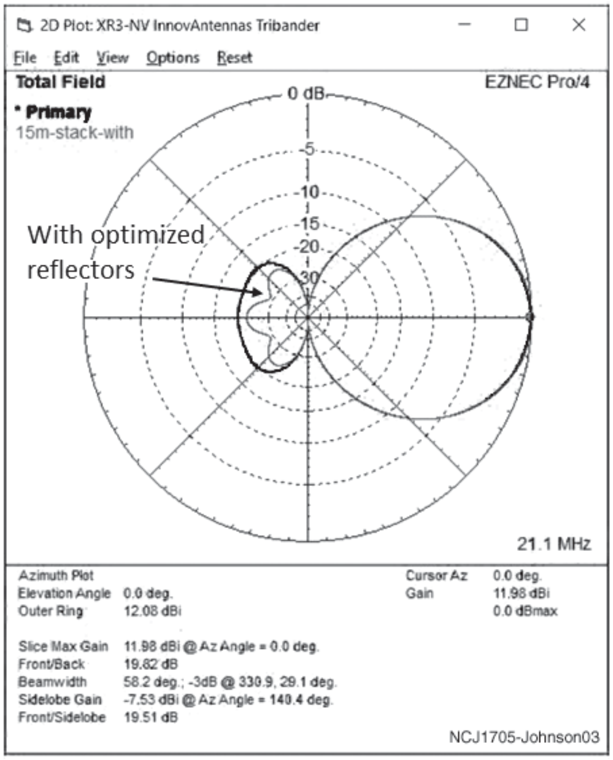

Figure 3 — 15 meter stack results with sub-array of 2 × 15-meter optimized reflectors and without.

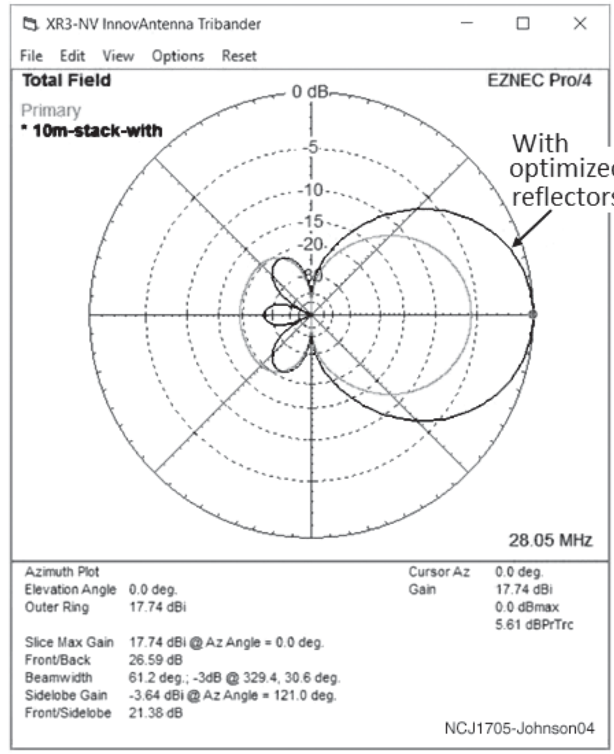

Figure 4 — 10-meter stack enhancements with sub-array of 2 × optimized reflectors and without.

ants and respective results, take a look at the layout in Figure 3 of three, more-tightly stacked XR3-NVs. In this instance we can see that only one additional element has been needed for significant advantages on 10 meters, along with a very small increase in gain on 15 (but a good amount of additional F/B). On 10 meters a massive loss in forward gain resulted from the exceptionally wide stack, which is brought back in line by the addition of these two 10-meter reflectors.

It is important to note that, as mentioned earlier, these additional reflectors are not in exactly the same boom positions as the main antennas, nor are they exactly the same length; they have been optimized for best performance.

Let's look at the possibilities for using such an arrangement at VHF. The most topical subject matter may come from 50 MHz and 70 MHz combinations, due to the market saturation of the Icom IC-7300s, IC-7100s, and more traditional FT-847s, which provide 50 MHz and 70 MHz on the same antenna socket [70 MHz is not available to US amateurs or on US product models. — *Ed*].

While many other VHF dual- or multi-band-options are available for consideration, not all combinations are ideal. The combination I am most asked for is 2 meters/70 centimeters, where hams ask if I have any designs. My short answer is always, "No, as the combination does not give best results." There is a 3rd-harmonic relationship between 70 centimeters and 2 meters, which ensures that the 2 meter element will conduct while 70 centimeters is in use. This usually causes a severe distortion in the 70-centimeter pattern. While it's possible to achieve a good SWR, pattern cleanliness on 70 centimeters is extremely unlikely. The same scenario exists for 50 MHz and 144 MHz, with the same challenging issues resulting on 144 MHz this time.

Back now to the 50/70 MHz combination. The typical European lot is very small. One of my most popular designs is the 8 element dualbander, with 4 active elements on each band and a total boom length of 2.1 meters. In addition, it is often the case that short booms are preferred for home or portable/contest use, in order to achieve wide beamwidth. Stacking two Yagis can provide up to 3 dB of additional gain over installing one while maintaining beamwidth. Two towers or masts with a pair of Yagis for one band on each, however, would be limiting and perhaps not even possible.

Tables 1 and 2 show the results of my work on a sub-array for this 8 element dualbander. It's been possible to extend the

Table 1
Results, per band: Net performance increase on 50 MHz over standard stack: 0.08 dB gain, 14.7dB F/B; 3.24 dB increase over single Yagi (1 additional free space element).

4.2 meters between antennas – 2.1 meters to free-space parasitic elements

Single Yagi	50 MHz	8.52 dBi	20.91 dB F/B
Stacked Yagis	50 MHz	11.68 dBi	17.34 dB F/B
Stacked Yagis, parasitic enhancement	11.76 dBi	26.46 dB F/B	

Table 2
Net performance increase on 70 MHz over standard stack is 0.71 dB gain, 6.05 dB F/B, a 3.8dB increase over a single Yagi (two additional free-space elements).

4.2 meters between antennas – 2.1 meters to free-space parasitic elements

Single Yagi	70 MHz	7.83 dBi	21.32 dB F/B
Stacked Yagis	70 MHz	10.92 dBi	18.67 dB F/B
Stacked Yagis w/ parasitic enhancement	11.63 dBi	24.72 dB F/B	

vertical spacing beyond what I would have considered as the usual ideal, by adding a reflector for the main/lowest band. This did not happen in the HF examples, as the vertical spacing available was not sufficient for this to produce an improvement.

For enhancement on 70 MHz, a parasitic element has been added forward of the first, another result of the wider spacing between the two Yagis.

In summary, the sub-array on 50 MHz has resulted in a net change over two Yagis spaced at 4.2 meters of 0.08 dB gain and 14.7dB F/B. The improvement over a single Yagi being 3.24 dB gain and 5.55 dB F/B (see Table 1). An overlay of the stack with and without the sub-array can be seen in Figure 5.

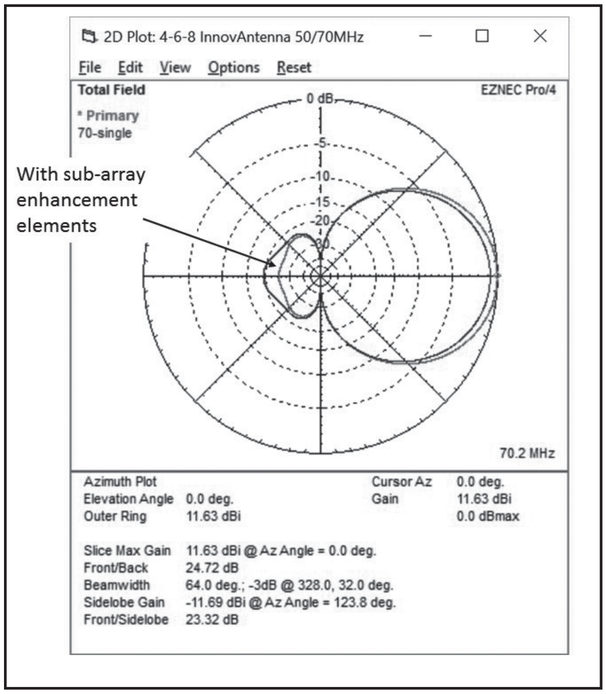

Figure 5 — 70 MHz performance of a vertical stack of 8 element 50 MHz/70 MHz duo band yagis with and without sub array elements.

On this band (and with a single reflector in addition to the two Yagis), very little change in gain is seen, although a significant improvement is seen in F/B ratio. Let's now look at the 70 MHz improvements below (see Table 2).

For 70 MHz the gains are far more significant with 0.71dB improvement over a standard stack along with a net 6.05 dB improvement in F/B. The performance delta between a single Yagi and the stack, including the sub-array, is 3.8 dB gain increase with more than 6 dB improvement in F/B at the same time.

In addition to the above experiment, I have also tried a number of my other 50/70 MHz dualband Yagis and had very similar improvement results, and, at the same time, proven that the variation in vertical stacking distance can be compensated by fewer or more parasitic elements in the sub-array, depending on the chosen distance.

Having achieved these results with multiband Yagis, I wondered if any usable benefit could be seen with monoband Yagis, in terms of performance and in the variation of stacking distance. So far, my experimentation has been limited to a handful of 2 meter Yagis, but the results have been encouraging, with improvements in both F/B and gain.

The benefits from a sub-array are not limited to the vertical stack; horizontal and box stacks can be enhanced with additional elements too.

Conclusion

The sub-array provides additional performance and adds flexibility to the stacked directional antenna while using space that does not extend the array in any direction. Sometimes mounting the elements in the locations where they are required may be challenging, and it is up to the experimenter to decide if the associated benefits are worthwhile — and certainly, those with dual or multiband directional antennas are very compelling indeed.