# Development and Real World Replication of Modern Yagi Antennas (III) - Manual Optimisation of Multiple Yagi Arrays

***by Justin Johnson, G0KSC***

Within this article we will discuss optimisation of Yagi stacking distances required in order to achieve the cleanest, tightest patterns / Front to Rear (F/R). While the DL6WU formula does provide a good basis from which to work, it is my finding that this calculation is more suited to more traditionally optimised Yagis than ultra clean Yagi antennas.

## Objectives

In my last article [1] I suggested we would look at stacking of OWL (Optimised Wide band Low impedance) Yagis but will start with an 11 element 144MHz LFA Yagi.

I have been asked for some large, complex stacked arrays in more recent years and in the interest of keeping radiation patterns as tight as the original single Yagi (or as close as possible), have spent time manually adjusting stacking distances in order to ensure best results. By best results, I mean to include symmetry in the final results while maintaining or bettering both F/R and F/B (Front to Back ratio) and avoiding (where possible) random 'spikes' appearing within either the elevation or azimuth planes.

It is important to note that this optimisation is not being carried out for absolute best sky temperature and/or G/T although the results prove not to be too far away from optimum in these areas. However, by achieving very high levels of F/R and reducing any 'spike' lobes to an absolute minimum, real-world experiences in terms of general noise level and/or birdies can be substantially reduced.

## How Yagis really look electromagnetically?

In more recent times we have become used to seeing ARRL style antenna plot tapers which perhaps make Yagis focused more heavily on gain than pattern, look better on paper than their on-air performance would suggest. To put this into perspective, below are two plots of the same 14 element G0KSC OWL 'Gain Focused' Yagi

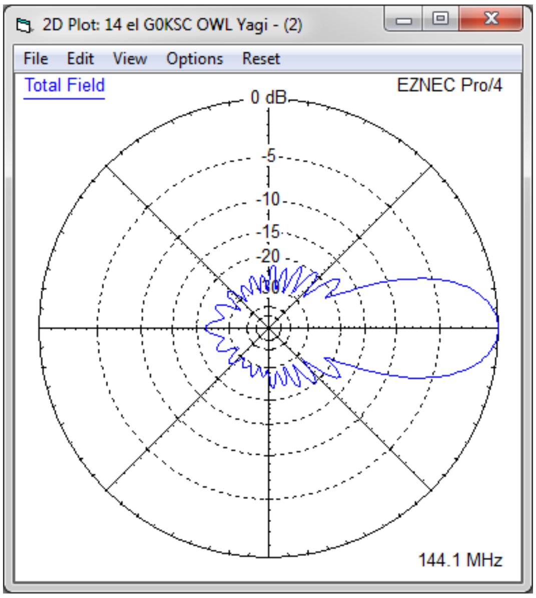



***Fig. 1: 14 el. OWL Yagi ARRL style plot***

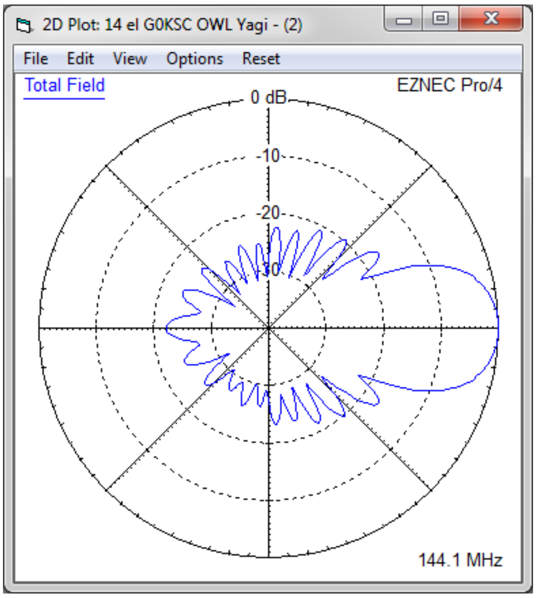



***Fig. 2: Ditto, but linear scale***

Fig. 1 above shows the elevation plot of this antenna in free space as we are used to viewing Yagis by means of an ARRL style plot, while fig. 2 presents the same antenna in a linear format. When comparing the forward lobe to all side lobes (in particular those beneath the antenna where these lobes will be looking at your shack, your neighbours and any other earth-side noise sources) the antenna appears to be far less impressive. However, the reverse applies when looking at lobes suppressed to levels better than 30dB. Take the following examples of an OWL with off-set folded dipole driven element where the feed point and dipole off-set has been arranged in favour of less unwanted lobes towards ground.

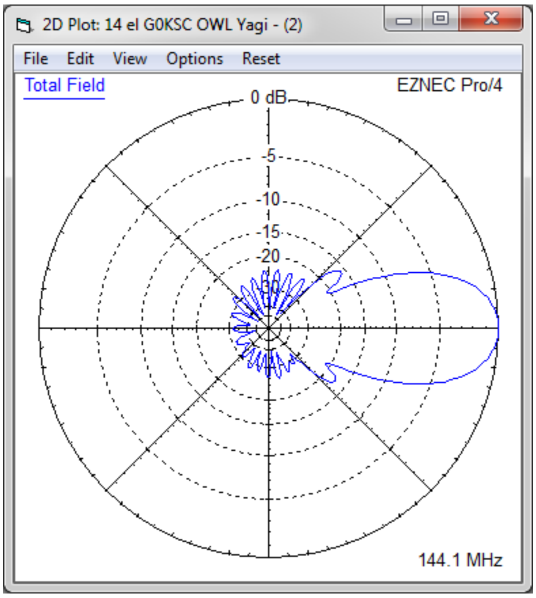



*Fig. 3: 14 el. OWL high suppression, ARRL style*

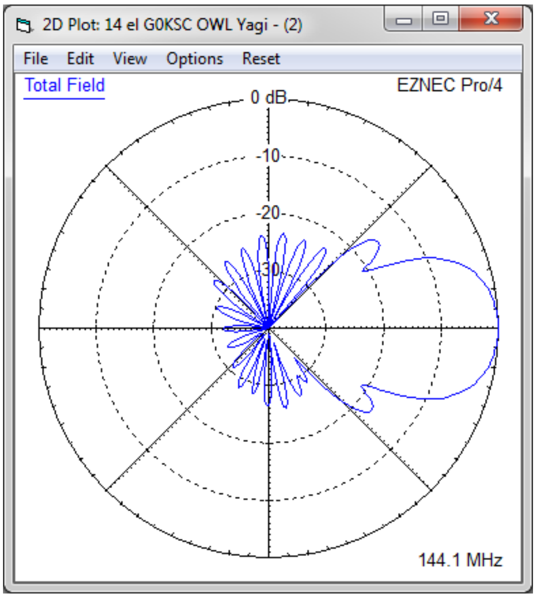



*Fig. 4: Ditto, linear scale*

When comparing the above plots (fig. 3 and fig. 4), a much more impressive level of suppression is seen from 45 degrees backwards in both examples, but when directly comparing the linear results of fig. 2 and fig. 4, we can begin to understand why hams see much lower 'real world' noise levels when using Yagi antennas optimised for minimum unwanted lobes.

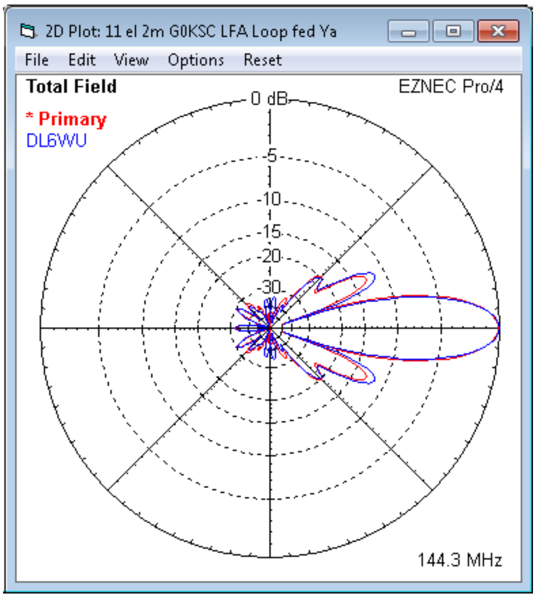
## Stacking more than 2 antennas in any direction

As mentioned above I have had many request both commercially and self-build for multiple Yagi arrays which extend with more than 2 antennas per plane. I had previously found that using the well regarded DL6WU formula produced interesting results with my Yagis. In many cases, going above the suggested stacking distance for a given array resulted in increased G/T figures (and in most cases, reduced sky temperature too) although side lobes became very large indeed. 'Under-stacking' (2 Yagis) from the DL6WU suggested measurements often drastically reduced side lobes without too much of a compromise in both sky temperature and G/T.

The first result above was puzzling to me until I went back to basics on the output that Tant produces when predicting sky temperature and G/T figures. The standard method of comparison used within Tant (and the VE7BQH list) is taken at 30 degrees elevation angle and therefore, if any larger side lobes (at this angle) do not point towards ground, a fair representation of assessment or comparison may not be seen. It is for this reason, when asked my opinion on stacking distances, I tend to ask the requirement and location of the suggested array, establish boom length and the purpose of use and then manually optimise. Ultimately, a tighter (than DL6WU suggested figures) stacking distance is the result although to maintain the levels of suppression (along with the avoidance of unwanted lobes or 'spikes') the stacking distance between each antenna needs to increase, the more Yagis are added.

This is often the case only when 2 Yagis are used (in either direction which could include an H frame with 4 antennas). If using these stacking distances with 4 or more of the same Yagi in any direction, in order to maintain pattern symmetry and cleanliness, the stacking distance between each antenna needs to increase; the more Yagis are added, the greater the distance required between each Yagi.

The results vary from one Yagi style/size to another and there is no fixed guideline to be used but the importance of manual optimisation should be considered when looking at multiple stacked Yagi configurations. Generally, if a single large spike sticks out from an otherwise clean pattern, the spacing between Yagis is not optimum. As an example, I have provided some plots for 11 element 144MHz LFA Yagis.



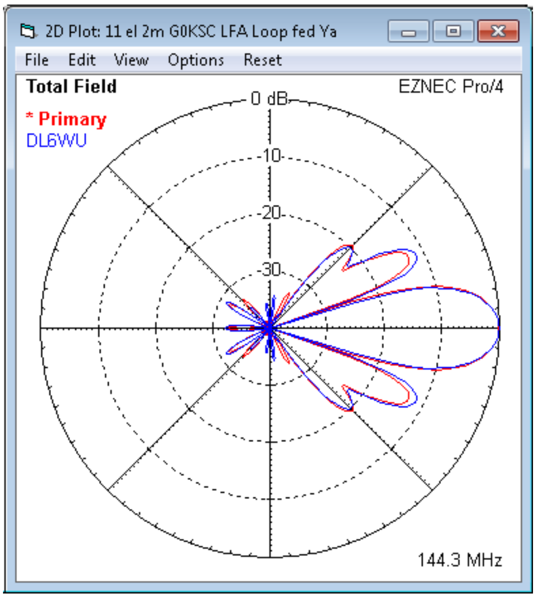
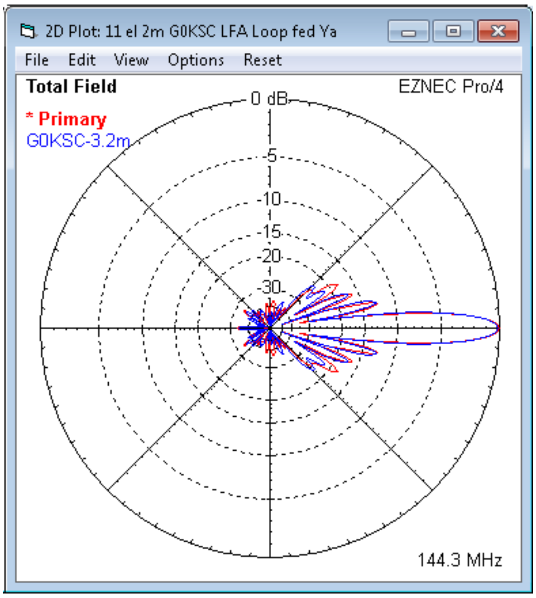




***Fig. 5: 2x11 el. 3,35m vs. 3,2m stack***

***Fig. 6: Ditto, linear scale***

Fig. 5 shows two plots overlaid using the typical ARRL style plots. The first example is 2 x 11el LFAs stacked at the DL6WU calculated 3.35m (vertical stack) versus the G0KSC calculated 3.2m spacing. The difference in unwanted lobes is quite marked (although forward gain is virtually identical). Not so much in the forward lobes, but those above and beneath the array. Fig. 6 shows the linear plot for the same arrangement which really highlights the difference in the two configurations. The lobes directly pointing upwards from the array would not be so troublesome but certainly the lobes pointing straight down could cause problems with unwanted noise. If this array with a 3.35m stacking distance was installed on your shack, these lobes could be susceptible to picking up shack noise. If being a part of a H frame with 4 antennas and being elevated, even at very high angles this array could still have Earth directed side lobes and thus susceptible to picking up unwanted noise. One note to make is the single antenna is extremely quiet to start with and therefore, with less quiet Yagis, the potential exists for more/larger unwanted lobes. Therefore, it is always good to experiment with various stacking configurations in software, before selecting an antenna for use as a part of a station. Now let us take a look at 4 antennas stacked using these same two sets of spacing.



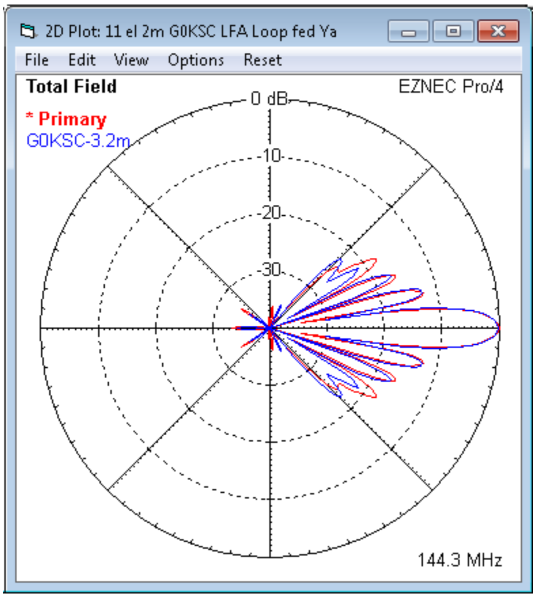




***Fig. 7: 4x11 el., 3,35m vs. 3,2m stack***

***Fig. 8: Ditto, linear scale***

Again it is the linear plot were we can see how much more linearity and symmetry the side lobe progression has with the 3.2m stack. So is this under-stacking or not?

I mentioned above that the more antennas there are in the stack, the greater the distance needed between them. To prove this point, I would like to conduct two experiments. The first plot below (fig. 9) shows 4 x 11el stacked at just 3.1m apart. The second plot (fig. 10) provides data for 2 antennas stacked at just 3.1m apart.

THIS ist about he first half of the complete article that was published in

**DUBUS Magazine**.

If you want to read the full article, including the German translation,

please order

the DUBUS magazine set (4 issues) for 2012  for 25 Euro

OR

the DUBUS book Technik 12  for 25 Euro

on

**www.DUBUS.org**

You can also place orders via Email:

**DUBUS@t-online.de**