Antenna Interactions – Part 2
Twisting Stacks

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Part I introduced meta-tools which give a more comprehensive view of an antenna system's radiation pattern, and which generate statistics about the system's performance towards certain target zones in the sky.[2] Available information about propagation elevation angles can assist in the proper selection of target zones. Now let's apply these tools to stacked Yagi systems as they might be used (or abused) in contests.

Note — The tables and text in this part refer to over 60 figures containing pattern maps, most of which are not included in the *NCJ* magazine. All figures and a complete copy of this article, as well as PowerPoint animations mentioned in the text, are available from the NCJ website: www.ncjweb.com.

1 Choosing statistics

Before launching into analysis of specific antenna systems, we should make a careful selection of the statistics used to characterize the performance of a system. To describe the overall gain of an antenna system across a range of elevation angles and azimuths, one might simply average the power across this space. Technically this is the "mean power" (expressed in dBi in our case). But a simple arithmetic mean can easily be shifted up (or down) by a significant amount if a few points have extremely high or low values.

A better statistic might be the "median", a number where half of the samples have values above the median and half have values below the median. In my meta-tools, a target zone between 2-24° elevation and 22-70° azimuth (covering 99.9% of European openings on 20m in undisturbed conditions from the Washington DC area) contains 1026 patches of sky. A median power gain of +11.7 dBi means 513 patches have power levels above +11.7 dBi and 513 have power levels below +11.7 dBi. A relatively small number of points with dramatically larger or smaller gain will not influence the median very much.

To understand how much the antenna pattern wanders above and below the median, the antenna pattern maps included with this article include the average difference of power above and below the median. For this article, we won't need this statistic. But we will be looking at the location and value of maximum and minimum power gain within the target zone and their impact on contesting performance.

The *NCJ* website contains an updated version of the meta-tool "noutrim.awk" which calculates median, mean difference of power above and below the median, and corrects a few minor bugs.

2 Reference points for stacks of two and three Yagis

Let's apply these new tools to specific antenna systems used in contesting stations around the Washington DC area. K4JA's large antenna farm includes a three-Yagi stack for 20m. The Yagis are identical: 6-element OWA designs on 48 foot booms. The Yagis are mounted at 50, 100 and 150 feet – typical mounting heights for 20m stacked Yagi systems.

Europe is the most critical target for K4JA. Table 1 shows the performance statistics of this system toward Europe. Each possible combination of bottom, middle, and top Yagis using in phase, equal current levels has been included in the Table. The maps and statistics provided by the meta-tools (see Figure 1 through Figure 12) expand the understanding of these combinations. In addition to the individual figures, the website contains a PowerPoint presentation "stack reference patterns.ppt" with the figures on separate slides. By jumping back and forth between slides on your computer screen, you can clearly see how two patterns compare.

			Europe 2-24° elev			best elevation range					
configuration			median	max	min	elev	% open	median	max	min	
bot			11.4	14.5	-0.5	*main lobe > elev range for 99½% open*					Figure 1
bot	mid		13.6	16.7	3.1	*main lobe = elev range for 99½% open*					Figure 2
bot	mid	top	12.8	18.2	-11.1	1-17°	95.2%	15.1	18.2	5.2	Figure 3, Figure 4
	mid		11.2	15.4	-6.3	2-18°	95.7%	12.8	15.4	5.2	Figure 5, Figure 6
		top	12.3	15.6	-8.9	1-12°	80.1%	12.9	15.6	4.5	Figure 7, Figure 8
bot		top	10.3	16.4	-24.2	2-16°	91.7%	13.5	16.4	3.7	Figure 9, Figure 10
	mid	top	11.8	17.7	-5.7	1-15°	88.9%	14.5	17.7	4.3	Figure 11, Figure 12

Table 1 — Reference results for 20m stack of 6-element OWA Yagis on 48 foot booms near Washington DC. Yagi heights are 50, 100 and 150 feet above good ground (σ =13.0 and conductivity = 5 mS/m). The stack is fed in phase with equal current. Median, maximum and minimum gain (dBi) are across the Europe target zone in the indicated range of elevation angles. "% open" is percent of all band openings covered by the specified elevation angle range.

When only the bottom Yagi antenna is fed, the median gain towards Europe is +11.4 dBi. However, at low elevation angles in the corners of the target zone (signals toward Scandinavia, Russia, Spain and Portugal) the gain falls to –0.5 dBi – not a very compelling signal when the band is first opening or closing to these parts of Europe! In general, much of the power is being radiated at elevation angles too high for the Europe zone.

Bottom + middle results in a better fit to the target zone. Median gain is +13.6 dBi, and minimum gain has improved to +3.1 dBi. The minimum gain occurs in the upper right and left corners of the zone – higher angles toward Scandinavia, Russia, Spain and Portugal. During the mature phase of the European opening on undisturbed days, when signals to the northeast USA are typically at higher elevation angles, the operator might drop down to the bottom Yagi alone to improve signals by 10 dB to these parts of Europe. Note that just rotating the bottom + middle stack towards Spain (for instance) does not achieve the same level of improvement at elevations above 17° as switching to the bottom Yagi alone.

The combination of all three Yagis has a median gain of +12.8 dBi – less than the bottom + middle configuration. A quick glance at the Figure 3 shows that elevation angles above 17° are not covered by this configuration. But at the very beginning and end of European openings, in disturbed conditions, and at certain points in the sunspot cycle the useable elevation angles are often quite low. Upon recalculating the statistics for a target zone of 1-17° elevation (Figure 4), the median gain jumps to +15.1 dBi – the highest of any combination of three Yagis. Within this narrower target, the minimum gain is +5.2 dBi at just 1° elevation in the lower left and right corners. This range of elevation angles covers 95% of all hours when 20m is open to Europe from the Washington DC area.

The remaining five permutations of 3-Yagi stack feeds provide patterns less attractive than the three discussed above. Median gains are lower and there are serious holes in the patterns at various parts of the target zone.

Conclusions about this European stack in the Washington DC area on 20m:

- Only three feed configurations are needed for a 3-Yagi stack: bottom, bottom + middle, and bottom + middle + top. All other in-phase equal-current feed combinations have inferior performance.
- Based on N6BV's propagation statistics, the contester can expect to have best performance from the bottom + middle + top feed configuration for about 85% of the hours over the course of the entire sunspot cycle when 20m is open to Europe, when elevation angles of ≤15° are used. Perhaps 5% of the time the operator will use the bottom + middle combination, and the remainder of the time the bottom-only feed appears best.
- Signals to northeastern Europe (Scandinavia, Russia) and southwestern Europe (Spain, Portugal) will be as much as −13 to −15 dB below the peak gain of the stack (depending on elevation angle required for the current conditions), when the stack is centered on Europe – not much better than a dipole at a suitable height! The stack must either be rotated to increase signal strength in one or the other of these regions, or the bottom antenna alone must be used.

The last bullet raises an important point. Reports of relative signal strength between stations during the contest can be quite misleading. A report that states "I tuned the 20m band at 1345z on Saturday here in Oslo. KC1XX was the same signal strength as K3LR, but 1 S-unit louder than W3LPL…" is providing only part of the story. One needs to know what antenna configuration was in use, and where it was pointed, at the various stations in order to draw conclusions about system performance!

3 Filling the target zone

With the dramatic variation in signal strength across the target zone, the antenna system designer is drawn to investigate potential improvements in coverage.

Could matters be improved if a smaller Yagi was used? As a quick test, the models were recalculated omitting the front director (probably less than optimal design for a 5-element OWA Yagi). Table 2 compares the resulting pattern statistics. The PowerPoint presentation "filling target.ppt" animates various possibilities for easy comparison.

Surprisingly, within the Europe target zone, the modes of gain for the non-optimized 5-element OWA stack are just -0.2 to -0.4 dB below that 6-element OWA stack. Yes, the 5-element OWA Yagi stack has a wider beam – but the overall gain within the Europe target is about the same. This becomes much clearer if you use the PowerPoint file on the website to flick between the 6- and 5-element versions.

Minimum gains within the zone occurred in the same places and were sometimes better and sometimes worse than the 6-element OWA stack. None of these variations are operationally significant on the spot frequency analyzed.

Outside the target zone, median gain improved with the 5-element OWA Yagis (i.e., the system was less sensitive to signals outside of Europe). The rear lobe is smaller in azimuth, leading to a quieter system. These statistics suggest that an optimized 5-element OWA Yagi on a boom of about 33 feet could have equivalent performance to a 6-element OWA Yagi in a stack system for coverage of Europe from the mid-Atlantic states, with a big reduction in costs!

Unfortunately I do not have a 4-element OWA design to model. However, on a spot frequency analysis, a 4-element OWA design equates approximately to a 3-element conventional Yagi. Figure 15 shows a two-Yagi stack of 3-element Yagis. Median gain is +12.4 dBi, down −1.2 dBi from the 6-element OWA. Variation from the median is smaller… but no significant improvement in actual power at the corners of the pattern occurred.

The 3-element conventional Yagi stack seems to be an unnecessary sacrifice of peak and overall gain without any better fill of the corners of the target zone.

configuration		Yagi	Europe					other		
			elev	median	mean dev	max	min	median	mean dev	
bot	6-el	2-24°	12.5	+1.1 −2.9	14.5	-0.5	-8.5	+10.9 −4.2	Figure 1	
	5-el		12.1	+1.1 −3.0	14.0	-0.9	-10.1	+12.8 −3.7	Figure 13	
bot mid	6-el	2-24°	13.6	+1.7 −3.1	16.7	3.2	-11.1	+12.1 −3.2	Figure 2	
	5-el		13.4	+1.7 −3.0	16.4	3.3	-13.6	+15.0 −1.3	Figure 14	
bot mid top	6-el	1-17°	15.1	+1.8 −3.2	18.2	5.2	-13.7	+14.8 −1.2	Figure 4	
	5-el		14.8	+1.7 −3.2	17.7	5.1	-14.3	+16.1 −0.7	Figure 16	

Table 2 — Comparison of pattern statistics for a 3-Yagi stack of 6- and 5-element OWA Yagis. The 5-element OWA Yagi is identical to the 6-element with the front director deleted.

What if we point the Yagis in slightly different directions in an attempt to smear out the pattern in azimuth to better fill the zone?

Table 3 compares the two-Yagi 6-element OWA stack performance when the stack is twisted open by various amounts. For this analysis I assumed that polar propagation paths (toward northeast Europe) are more likely to require lower takeoff angles than paths to the remainder of the continent. Therefore I twisted the higher Yagi towards the north. The configurations at the top of the table remain centered on 46° azimuth; the configurations at the bottom of the table twist only the top antenna to point more towards northeast Europe. For reference, the first line of the table contains pattern statistics for an untwisted stack. The PowerPoint file "Europe twist open.ppt", when started as a slide show, will automatically step through the cases in order as an animation, allowing you to see the impact of increasing twist on the pattern.

Yagi az		Europe			NE Eu 22° az			SW Eu 70° az			other	
bot	top	median	max	min	el: 2°	peak	24	el: 2°	peak	24	median	
46°	46°	13.6	16.7	3.2	5.4	14.3 @ 13°	5	5.4	14.3 @ 13°	5	-11.1	Figure 2
44°	48°	13.6	16.7	2.2	5.5	14.5 @ 12°	1	5.2	14.4 @ 13°	5	-10.9	Figure 17
42°	50°	13.6	16.6	1.0	5.6	14.5 @ 12°	1	5.1	14.3 @ 13°	4	-10.5	Figure 18
41°	51°	13.5	16.6	0.3	5.6	14.5 @ 12°	0	5.0	14.2 @ 13°	5	-10.2	Figure 19
40°	52°	13.5	16.6	-0.4	5.7	14.5 @ 12°	-0.	4.9	14.0 @ 14°	5	-9.9	Figure 20
42°	46°	13.6	16.7	2.6	5.9	14.9 @ 13°	2	4.8	13.9 @ 12°	3	-10.9	Figure 21

Table 3 — Two-Yagi European stack twisted open to varying degrees. Gain at the bottom and top corners of the target zone, and peak gain along the left and right edges of the target zone, are listed in the middle columns.

The table reveals that the pattern to northeast Europe improves only very slightly at the lowest elevation angles, and degrades significantly at 24° elevation, as the stack is twisted open while keeping it centered on Europe. If the stack is twisted open and shifted slightly towards the north, gain at lower elevation angles improves about a ½ dB, but with a -2.7 dBi reduction at the highest elevation. At the opposite edge, toward southwest Europe, pattern impairments are at most -½ dB and no operationally important improvements occur at any elevation angle. The trends, as the stack is twisted more and more open, are generally unfavorable.

Conclusions:

- Sacrificing peak gain to increase performance at the corners and edges of the target area doesn't appear to pay off. While a stack of 5-element OWA Yagis fills the target almost as well as a stack of 6-element OWA Yagis, there is no improvement in the edges and corners. Even a stack of 3-element Yagis does not improve gain at the edges.
- Twisting open a stack by as much as 10° in azimuth does not improve the fill of the Europe target zone and, in many respects, degrades coverage of the target. The trends suggest that continuing to twist open the stack by more than 10° will do more harm than good.

4 Covering two separated targets

At various times during the contest 20m opens to several continents simultaneously, or even to all continents. Contesters blessed with stacked Yagi systems sometimes attempt to manage these situations by splitting the stack open with each Yagi pointing in different directions. Beware: twisted stacks may contain unexpected and unpleasant surprises which can damage contest performance!

Let's begin with a benign case, again using a two-Yagi stack of 6-element OWA Yagis in the Washington DC area. The band is open to South America and Australia/New Zealand late at night in November. The operator responds by pointing the bottom antenna to South America and the top antenna to VK/ZL. N6BV's propaga tion statistics bear out the operator's assumption that the longer path to VK/ZL requires lower elevation angles.

Figure 22 shows the pattern meets expectations: two well-defined, separated beams focused on the targets. Gain to VK/ZL peaks at +12.5 dBi, and to South America at +11.7 dBi. These values are –3.1 and -2.8 dB below the peak for each antenna operated alone, reflecting the equal split of power. Median gains in the target zones are identical at +9.1 dBi. Median gain for areas outside of the two targets is –7.0 dBi, not nearly as quiet as the situation of untwisted Yagi stacks but a small price to pay for dual continent coverage.

If the operator had access to a three-Yagi stack, using the top two Yagis on VK/ZL would lower the main lobe to 7° elevation, a better fit for the VK/ZL target. But using a conventional three-Yagi power feed would result in double the power towards VK/ZL. Figure 23 shows the VK/ZL target with a peak gain of +15.9 dBi and a median of +13.5 dBi. The South America target has declined to a peak of +9.9 dBi and median of +7.4 dBi.

If the operator didn't like that power distribution, the bottom and middle Yagis could be pointed to South America and the top alone pointed to VK/ZL. Figure 24 shows the VK/ZL lobe still squeezes under the top edge of the target zone with a peak of +11.2 dBi and median of +8.6 dBi. The South American target has a well-centered lobe of +15.0 dBi peak and +11.4 dBi median.

The Powerpoint presentation "VK ZL and SA.ppt" allows you to compare these two power distributions. Armed with precise knowledge, the operator can choose which power distribution best fits his contest strategy at the moment.

More generally:

- Splitting stacks into directions which are more that 90° apart yields independent, well-defined lobes.
- Stacks with more than two Yagis provide the operator an opportunity to favor one target over another, although Yagis of the correct height must be chosen for each target.

5 Covering two adjacent targets

Late on a Sunday morning, during the middle of the European run, the 20m operator discovers a Botswana multiplier with a huge pileup. Not wanting to sacrifice his running frequency, the operator rotates the top Yagi of his two-Yagi stack to 90°, the azimuth to Botswana from his Virginia QTH. Between CQs on his run frequency, the operator attempts to crack the pileup. After many frustrating attempts, the operator notes his European run rate has dwindled significantly. With a sigh, he abandons his attempt to bag a valuable multiplier.

Figure 25 illustrates the operator's problem. By splitting his stack, his strongest signal was neither pointed toward Europe nor toward Botswana: peak gain is at 87° azimuth. Median gain to Europe is +10.1 dBi, down –3.5 dB from an untwisted stack. Likewise signals over the range of elevation angles which might be working to Botswana are down –3.4 dB from what a stack could produce, if focused purely on Botswana. With that big pileup, the operator will want all the gain he can obtain to get in and out quickly.

More generally, whenever Yagis in a stack are pointed in directions separated by <90° azimuth, the main lobes of each individual antenna are sucked together into a single beam, hovering between the azimuths of the Yagis. This single beam can be stretched out across the horizon. The animated PowerPoint files "twisting open 2 yagis.ppt" and "twisting 3 yagis.ppt" show a two- and three-Yagi stack being twisted apart in 5° increments of azimuth until its beams finally separate at a twist of 90°.

This "sticky" characteristic of twisted stacks can be used to advantage in contests. For example, during the morning 20m European opening in the Washington DC area, central and southeast Asia stations may also be available on arctic polar paths – a source of valuable multipliers, especially as casual operators in that part of the world get on the air during their local evening hours. Elevation angles to this target are quite low: 1 to 9°, so the top antenna is the one to twist away from Europe. Table 4 and Table 5 summarize stack performance to Europe and Asia at various combinations of azimuths for two- and three-Yagi stacks.

For two-Yagi stacks, the variations in overall gain into the target zones over a large range of azimuth pairs are small: <1 dB. Gain to Asia (median gain over the target) improves by +9½ to +11 dB. Gain to Europe degrades by -2¾ to -4 dB. More significant are the responses at the edges and corners of the zones. Gain at some elevation angles to southwest Europe degrades -5 to -8 dB, making a 1.5 kW signal into Spain weaker than a guy running 750 watts into a dipole at an appropriate height. Notice that the point of peak gain of the array slides off towards the north, away from Europe, and a bit too high to propagate into central Asia. The operator will have to exercise good judgment in deciding if the reduced signal strength into Europe, especially southwest Europe, is worth the potential for attracting Asian multipliers with a louder signal.

azimuth		Europe 2-24° elev			Asia 1-9° elev			else-where	mean As + Eu		
bot	top	median	max	min	median	max	min		median	min	
46°	46°	13.6	16.7	3.1	-0.8	13.7	-28.0	-11.2			Figure 2
41°	1°	10.4	15.2	-4.1	9.2	14.7	-4.1	-6.6	9.82	-4.09	Figure 26
41°	356°	10.1	14.7	-4.7	**9.9**	14.3	-2.8	-6.3	9.99	-3.64	Figure 27
41°	351°	9.9	14.1	-5.0	**10.1**	13.9	-1.8	-6.1	9.99	-3.08	Figure 28
41°	346°	9.8	13.5	-5.0	**9.9**	13.5	**-1.0**	-6.0	9.84	-2.54	Figure 29
46°	1°	**10.5**	14.8	-3.1	9.0	14.3	-4.2	-6.3	9.89	-3.59	Figure 30
46°	356°	10.4	14.3	-3.6	9.6	13.9	-2.9	-6.1	**10.03**	-3.22	Figure 31
46°	351°	10.2	13.7	-3.8	**9.8**	13.5	-1.9	-6.0	9.98	-2.72	Figure 32
46°	346°	10.0	13.1	-3.8	9.6	13.1	**-1.0**	-6.1	9.80	**-2.22**	Figure 33
51°	1°	**10.8**	14.4	-2.3	8.8	13.9	-4.2	-6.1	9.90	-3.12	Figure 34
51°	356°	**10.5**	13.9	-2.7	9.5	13.5	-2.9	-6.1	**10.04**	-2.79	Figure 35
51°	351°	10.4	13.2	-2.9	9.5	13.1	-1.9	-6.1	9.94	-2.35	Figure 36
51°	346°	10.2	12.5	-2.9	9.3	12.7	**-1.1**	-6.2	9.77	**-1.89**	Figure 37
56°	1°	**10.9**	13.9	**-1.6**	8.7	13.5	-4.2	-6.0	9.91	-2.71	Figure 38
56°	356°	**10.6**	13.4	**-2.0**	9.3	13.1	-2.9	-6.1	**10.01**	-2.43	Figure 39
56°	351°	10.4	12.7	-2.2	9.2	12.7	-1.8	-6.2	9.88	-2.02	Figure 40
56°	346°	10.3	11.9	-2.2	9.0	12.4	-1.5	-6.2	9.69	**-1.83**	Figure 41
56°	341°	10.0	11.4	-2.2	8.8	12.2	-2.5	-6.2	9.46	-2.33	Figure 42

Table 4 — Stack of two Yagis as described in the reference configurations of Table 1. The top antenna is twisted to extend pattern coverage into Asia. "Elsewhere" is the median gain in the untargeted directions. "mean Asia + Europe" is an equal-weighted average of the power to the Europe target zone and to the Asia target zone (converted to gain in dBi). Best values in key categories have been highlighted.

azimuth		Europe 2-24° elev			Asia 1-9° elev			else-where	mean As + Eu		
bot+mid	top	median	max	min	median	max	min		median	min	
46°	unused	13.6	16.7	3.1	-0.8	13.7	-28.0	-11.2			Figure 2
41°	1°	11.7	16.8	-9.1	10.7	16.7	-2.3	-10.0	11.24	-4.60	Figure 43
41°	356°	11.7	16.4	-8.3	**11.1**	16.3	-1.1	-9.5	**11.41**	-3.39	Figure 44
41°	351°	11.6	16.0	-7.7	**11.3**	16.0	-0.1	-9.1	**11.46**	-2.41	Figure 45
41°	346°	11.6	15.7	-6.7	**11.2**	15.5	0.7	-8.8	**11.42**	-1.58	Figure 46
41°	341°	11.7	15.3	-4.7	**11.1**	15.1	1.3	-8.6	**11.39**	-0.74	Figure 47
41°	336°	11.6	15.1	-2.7	**11.1**	14.6	**1.7**	-8.4	**11.36**	0.04	Figure 48
41°	331°	11.7	15.0	-1.1	**10.9**	14.2	**1.9**	-8.2	**11.28**	**0.66**	Figure 49
41°	326°	11.7	14.9	**0.2**	10.3	13.8	**1.8**	-8.1	11.06	**1.03**	Figure 50
41°	321°	11.7	14.9	**0.2**	9.9	13.4	0.9	-8.0	10.87	0.55	Figure 51
46°	1°	**12.1**	16.4	-8.3	10.1	16.1	-2.6	-9.5	11.23	-4.59	Figure 52
46°	356°	**12.0**	16.0	-7.6	10.5	15.7	-1.3	-9.1	**11.33**	-3.40	Figure 53
46°	351°	**12.1**	15.7	-7.1	10.7	15.4	-0.2	-8.8	**11.44**	-2.44	Figure 54
46°	346°	**12.0**	15.3	-6.8	10.7	14.9	0.6	-8.6	**11.35**	-1.69	Figure 55
46°	341°	**11.9**	15.1	-5.5	10.7	14.4	1.2	-8.4	**11.35**	-0.98	Figure 56
46°	336°	12.0	15.0	-3.7	10.6	13.9	**1.6**	-8.2	**11.36**	-0.30	Figure 57
46°	331°	**11.9**	14.9	-2.1	10.2	13.5	**1.8**	-8.1	11.14	**0.25**	Figure 58
46°	326°	**11.9**	14.9	-0.8	9.7	13.0	0.9	-8.0	10.90	0.12	Figure 59
51°	1°	**12.2**	16.0	-7.7	9.6	15.4	-2.7	-9.1	11.09	-4.48	Figure 60
51°	356°	**12.2**	15.7	-7.2	10.0	15.0	-1.3	-8.8	11.23	-3.33	Figure 61
51°	351°	**12.1**	15.3	-6.8	10.3	14.6	-0.3	-8.6	**11.27**	-2.40	Figure 62
51°	346°	**12.0**	15.1	-6.5	10.2	14.1	0.6	-8.4	11.17	-1.68	Figure 63
51°	341°	**12.0**	15.0	-6.1	10.3	13.6	1.2	-8.2	**11.27**	-1.11	Figure 64
51°	336°	**11.9**	14.9	-4.9	10.1	13.1	**1.6**	-8.1	11.09	-0.57	Figure 65
51°	331°	**11.8**	14.9	-3.3	9.7	12.5	0.9	-8.0	10.88	-0.73	Figure 66

Table 5 — Stack of three Yagis as described in the reference configurations of Table 1. Only top antenna is twisted to extend pattern coverage into Asia.

The three-Yagi stack offers fewer compromises. Leaving the bottom two Yagis towards Europe while diverting power via the top Yagi to Aisa keeps the Europe target zone covered with signals just -1½ to -2 dB down from the "two-Yagis on Europe only" case. Coverage of the Asia target zone improves by +11 to +12 dB. Signals in untargeted directions are reduced by about -2½ dB compared to the two-Yagi twisted stack. The point of peak gain in the array moves slightly but remains in the Europe target zone. The overall pattern shape fits the Europe and Asia target zones much better than with the two-Yagi stack.

But there is an important danger! Figure 52 has the top Yagi twisted to 1°, e.g., to work a 9V1 multiplier. The low and middle Yagis are still pointing to Europe at 46°. Here that twisted top Yagi has taken a –8 to –13 dB bite out of signal strength to Scandinavia and western Russia in the upper right corner of the Europe target zone! This cancellation trough could have an unfavorable impact on QSO rate.

This cancellation troughs can be worked around, if the operator knows the situation. One workaround is to *over-twist* the stack: in this case, to move the top antenna an extra amount to the left, and the bottom antennas an extra amount to the right. Figure 64 twists the top antenna an extra 20° left, and the bottom two Yagis 5° right. Median gains to Europe and to Asia are practically identical – but the cancellation trough that was killing signals into Scandinavia and western Russia has moved out of the way.

Conclusions:

- While stacked Yagis twisted apart by more than 90° in azimuth have independent lobes, a twist of <90° causes lobes to merge together with a signal peak in the direction *between* the twisted Yagis. As a result, the uninformed operator may believe he is loud in two directions when in fact his peak signal is loudest only in *one, wrong* direction.
- Stacks of three or more Yagis, when twisted, may contain signal cancellations exceeding –10 dB. These cancellations may lie in operationally important azimuths and elevations, resulting in lower QSO rates and missed multipliers. The skilled contester must understand these patterns and take steps to avoid compromising his signal, e.g., by over-twisting the stack.

To reinforce this last point, examine a final scenario: W3LPL's main 20m tower contains a stack of 5-element (conventional, not OWA) Yagis at 50 and 100 feet fixed on Europe. At the top of the tower is a 5-element rotatable Yagi at 200 feet for chasing multipliers. The operator can feed the stack alone or the stack plus the high rotatable. This model assumes 50% of the power goes to the high antenna and the remaining 50% is divided into the two Yagis of the stack… and that all the antennas are fed in phase.

Figure 67 shows the result: a severe pattern cancellation in the middle of the Europe target zone when the multiplier antenna is pointing to 9V1 at 1° azimuth. Compared to the two-Yagi stack fed alone, signals in parts of Europe are cut by over –18 dB to levels below –3 dBi! Over-twisting can not correct this problem.

But another technique will fix pattern cancellations like this one. We'll explore it in the next part.