Antenna Interactions—Part 5
How Close is Too Close?

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Reviewing Progress to Date

Part 1 introduced meta-tools that give more comprehensive maps and statistics about antenna radiation patterns.[2]

Part 2 applied those meta-tools to twisted stacked Yagis with the antennas pointing in different directions and identified some problem situations that contesters may encounter.[3]

Part 3 examined self interactions of unused antennas within a stack, applying a new meta-tool to compare complete sky hemisphere patterns. Examples of siting problems in the design of a contesting station antenna farm were given but siting issues were not fully explored.[4]

Part 4 introduced the use of current tapering to clean up stack patterns.[5]

In this part, we return to the relationship between antenna location and pattern impairments. We begin by focusing on multiple Yagis for the same band.

Collocation on a Tower with a Tall Stack

Part 3 showed that an unused OWA Yagi placed 3/4 λ above a two Yagi stack (also with 3/4 λ spacing) shows little interaction. Essentially no pattern change to the stack occurs when one short circuits the unused OWA Yagi's feed-point and rotates the Yagi 90° to the stack's azimuth. Many contest locations in North America may exploit this result. For example, in the northeast USA a European stack points toward about 45° azimuth; South America and the Caribbean center around 155°. The station designer wants to place a Yagi fixed on South America, and on the same tower as a European stack. How close can one place the South American Yagi without unduly degrading the stack's pattern?

Table 1 shows pattern impairments to a two Yagi stack. The stack points to Europe and contains two OWA 20 meter Yagis, each with six elements on a 48 foot boom. The stack is "tall spacing", 3/4 and 1 1/2 λ heights, and current tapered feeding occurs (0.81 top; 1.00 bottom). A third Yagi of identical design, oriented toward 155°, stands at the heights specified in each row of the table. This third Yagi has a shorted feed-point. The first line of the table shows the performance characteristics of this European stack alone (no other antenna present). The remainder of the table summarizes four types of pattern impairments introduced by the South America Yagi:

Change in median gain for the Europe target zone (22-70° azimuth; 2-22° elevation).

Change in the minimum gain within the Europe target zone.

Change in median gain outside the Europe target zone.

Location and gain of the worst minor lobe.

Maximum change (both increase and decrease) in the spot gains outside the target zone.

As in previous parts, we clamp a floor of –15 dBi to all pattern gains below –15 dBi.

The South America Yagi exhibits minimal effect on the stack's main beam at most heights. Even when mounted just 1/8 λ above or below one of the stack's constituent antennas, the overall impact to the European sector's median (overall) gain is only about –1/2 dB—not op-

Table 1

Impairments caused by a single Yagi collocated on the same tower as a tall two-Yagi stack. The stack stands at 3/4 and 1 1/2 λ height. All antennas are 6 element OWA 20 meter Yagis on 48 foot booms. The single Yagi is not fed and its feed-point is shorted. The stack is fed with a 0.81 (top) 1.00 (bottom) current taper. Based on a mid-Atlantic USA location, the single Yagi points to South America, an azimuth 110° from the European stack. The top of the table gives pattern statistics for the stack without the presence of the single Yagi.

	target median gain (dBi)	*target minimum gain (dBi)*	*non-target median gain (dBi)*	*worst non-target lobe (dBi, location)*	*% sky below -15 dBi*
stack only	*13.79*	*5.49*	*-10.87*	*+1.60 az 252° el 11°*	*28.4%*

single Yagi height	*change in target median gain (dB)*	*change in target minimum gain (dB)*	*largest decrease in target gain (dB)*	*largest increase in target gain (dB)*	*change in non-target median gain (dB)*	*change in worst non-target lobe gain (dB) (location if changed)*	*largest decrease in non-target gain (dB)*	*largest incrrease in non-target gain (dB)*	*change % sky below -15 dBi*
2 1/4 λ	+0.02	-0.08	-0.08	+0.10	0.00	0.00 az 201° el 11°	-3.73	+3.95	-1.6%
2 λ	+0.03	-0.31	-0.31	+0.45	+0.07	-0.05 az 254° el 11°	-5.60	+6.46	-3.9%
1 3/4 λ	-0.08	-0.42	-0.42	+0.31	+1.47	+0.37 az 250° el 11°	-7.77	+11.00	-15.9%
1 5/8 λ	-0.50	-1.14	-1.14	+0.39	+4.12	+2.15 az 229° el 10°	-7.95	+17.75	-19.5%
1 1/2 λ			— collides with top Yagi in stack —						
1 3/8 λ	-0.54	-1.26	-1.26	+0.01	+4.70	+2.07 az 231° el 10°	-7.15	+18.15	-22.5%
1 1/4 λ	-0.14	-0.55	-0.58	+0.19	+3.49	+1.35 az 105° el 11°	-13.13	+13.50	-22.0%
1 1/6 λ	-0.08	-0.50	-0.68	+0.25	+3.19	+1.26 az 105° el 11°	-13.36	+13.70	-21.0%
1 λ	-0.13	-0.56	-0.87	+0.36	+3.69	+1.43 az 105° el 11°	-10.99	+14.13	-19.9%
7/8 λ	-0.65	-0.95	-2.05	-0.25	+5.71	+2.94 az 145° el 15°	-6.43	+19.38	-20.5%
3/4 λ			— collides with bottom Yagi in stack —						
5/8 λ	-0.63	-0.74	-1.97	-0.04	+5.78	+2.23 az 149° el 21°	-6.13	+18.76	-17.8%
1/2 λ	-0.08	-0.25	-0.70	+0.22	+3.24	+0.23 az 247° el 11°	-9.38	+11.65	-19.4%
1/4 λ	-0.01	-0.02	-0.26	+0.08	+1.31	-0.32 az 252° el 11°	-3.16	+5.87	-13.4%

erationally significant. If mounted 1/8 λ above or below the top Yagi of the stack, some spots within the European sector experience about –1 dB degradation in the worst case. When mounted 1/8 λ above or below the bottom Yagi of the stack, some spots within the European sector see degradations of –2 dB.

So, we can just stick the South America Yagi up on the tower at a convenient spot with little concern, as long as we stay at least 1/8 λ (about 8 feet on 20 meters) away from the other antennas, right? Well—maybe not.

The right side of the table reveals a much more significant impact on the stack in directions outside of the main beam—the QRM and QRN generating directions. Median gain for all directions outside of Europe rises as much as 6 dB. In some spot directions signals jump 19 dB. Where once 28% of the sky hemisphere was very quiet, with gains below –15 dBi, now the sky fills in with minor lobes.

This filling-in of the sky is not uniform. While some azimuths and elevations may see signals increase by as much as 19 dB, other spots will see a decrease in signals. The change in median gain outside of the target zone reflects the *overall* degradation of QRM rejecting ability. The column labeled "largest increase in gain" shows the worst spot degradation of pattern. The station designer can now choose what overall degradation he is willing to tolerate, in exchange for the benefit of a fixed South America Yagi on the same tower. And he also can choose the worst spot degradation that he is willing to tolerate.

For example, when the South America Yagi stands more than 1/4 λ above or below the stack, overall QRM rejecting ability degrades by 2 dB—but some particular azimuths and elevations experience much worse increases: up to 11.7 dB degradation.

By locating the South America Yagi 1/2 λ above the stack, overall QRM change is nil—some directions are quieter, and others a bit noisier. An extra 4% of the sky has gain above –15 dBi—not very much. In the worst case a specific QRM signal might increase 6 1/2 dB, just over an S-unit. This location might be a reasonable trade-off of QRM fighting ability for the convenience of a fixed antenna on South America.

Of course, such a high antenna toward South America will not have an optimal pattern as its main lobe contains a big null at important elevation angles. So perhaps collocation with a tall stack is not a good idea, if one can avoid it.

What about collocating with a short stack?

Collocation on a tower with a short stack

Table 2 shows pattern impairments introduced by a South America Yagi to a current-tapered (0.81 top; 1.00 bottom), two Yagi European stack with "short spacing": 1/2 and 1 λ heights. The Yagi designs and azimuths are identical to those discussed in the previous section. The previous part to this series showed that this stack has a far cleaner pattern than the tall stack, with 56% of the sky exhibiting gains below –15 dBi.

Similar degradations occur to this stack. Once the South America Yagi moves to within 1/2 λ of the stack's antennas, the sky starts filling up with minor lobes. But the short stack seems a bit more tolerant of the extra antenna above it. That South American Yagi can sit 3/8 λ above the stack (i.e., at 1 3/8λ total height) for about the same degradation as experienced by 1/2 λ separation above the tall stack.

A Yagi at 1 3/8 λ or even 1 1/2 λ height will be effective much of the time to South America. Take off angles on 20 meters from the mid-Atlantic region of the USA range up to 24° or so. With a pattern null centered around 20-24°, these high South American Yagis will be fine except during the 3-4% of opening hours from W3 when the higher angles are required. The current-tapered short European stack with a South American Yagi at 1 3/8 λ height above should work much better than a current-tapered tall European stack with a South American Yagi at 2 λ height.

But we've only looked at half of the story.

Impact of stack on South America Yagi

How badly does the presence of the European stack affect the pattern of the South American Yagi? Table 3 reveals a somewhat uglier result.

The table compares the South American Yagi alone to the configuration with a collocated short stack with its feedpoints shorted. The pattern statistics for the South American Yagi alone differ for each mounting height. The target zone for South America tops out at 24° eleva-

Table 2

Impairments caused by a single Yagi collocated on the same tower as a short two Yagi stack. The stack stands at 1/2 and 1 l high. Yagi design, drive currents, and orientation otherwise are identical to Table 1.

	target median gain (dBi)	*target minimum gain (dBi)*			*non-target median gain (dBi)*	*worst non-target lobe (dBi, location)*			*% sky below -15 dBi*
stack only	*13.44*	*1.38*			*-15.00*	*-0.57 AZ 252° el 11°*			*55.5%*

single Yagi height	*change in target median gain (dB)*	*change in target minimum gain (dB)*	*largest decrease in target gain (dB)*	*largest increase in target gain (dB)*	*change in non-target median gain (dB)*	*change in worst non-target lobe gain (dB) (location if changed)*	*largest decrease in non-target gain (dB)*	*largest incrrease in non-target gain (dB)*	*change % sky below -15 dBi*
1 1/2 λ	0.00	-0.18	-0.18	+0.06	0.00	+0.25 az 100° el 14°	-4.94	+4.23	-0.3%
1 3/8 λ	-0.02	-0.29	-0.29	+0.06	0.00	+0.55 az 100° el 14°	-5.94	+6.81	-3.3%
1 1/4 λ	-0.10	-0.48	-0.48	0.00	+0.78	+1.11 az 100° el 14°	-3.36	+11.73	-9.9%
1 1/8 λ	-0.74	-1.47	-1.47	-0.50	+6.48	+4.58 az 151° el 11°	-2.75	+18.29	-40.2%
1-1/16 λ	-1.88	-3.28	-3.28	-1.27	+10.92	+6.96 az 149° el 12°	-4.25	+20.82	-50.7%
1 λ			— collides with top Yagi in stack —						
7/8 λ	-0.98	-1.72	-1.72	-0.63	+7.56	+5.40 az 151° el 15°	-3.35	+18.69	-49.1%
3/4 λ	-0.43	-0.93	-1.02	-0.21	+4.70	+3.81 az 154° el 17°	-3.35	+17.37	-29.7%
5/8 λ	-0.84	-1.15	-1.76	-0.50	+8.42	+6.29 az 152° el 19°	-3.58	+18.67	-44.5%
1/2 λ			— collides with bottom Yagi in stack —						
3/8 λ	-0.68	-0.77	-1.36	-0.41	+9.19	+4.08 az 152° el 25°	-3.63	+16.24	-48.5?
1/4 λ	-0.11	-0.23	-0.34	0.00	+3.50	+0.68 az 100° el 18°	-3.22	+10.07	-23.4%

tion. But the lowest mounting heights do not yield good signals at very low take-off angles, so the target sector's lowest elevation angle is set a little higher, as indicated in the table, for the lowest mounting heights.

The stack disrupts the pattern of the single South American Yagi more than the single Yagi affected the stack. The main beam to South America is much more disturbed; even at 1/2 λ spacing the median gain declines by 0.6 dB. At 3/8 λ spacing median gain is down 1.2 dB, and 3.4 dB at 1/8 λ spacing. These gain degradations occur uniformly over the entire main beam—not just in a few spot locations. While a couple of dB may not be terribly significant except in marginal conditions, these figures greatly exceed the main beam impairment shown in the previous section's scenario. Probably the presence of more unused aluminum, cluttering up the near field of the South America Yagi, contributes to the larger impairments.

Similarly, the South America Yagi's non-target sector fills in with more minor lobes, and minor lobes with larger gains. At 3/8 λ spacing some minor lobes are up over 9 dB—and even at 1/2 λ spacing some minor lobes increase 7 dB.

When designing collocated systems, first seek to reduce impairments caused by the stack until those impairments fall below the design goal. A quick check of impairments caused by the single Yagi to the stack then can verify achievement of the design goal when the stack is fed.

Conclusions about tower collocation

Although not an exhaustive study of same-tower collocation of different antenna system, we can propose some design guidelines for the interaction of two collocated antenna systems for the same band, where one system contains a single Yagi and the other stacked Yagis:

Earlier parts of this series showed that pointing the two systems to azimuths differing by 90° reduces interactions.

At least for OWA designs, short-circuiting the feed-point of unused antennas (rather than open-circuiting the feed-point) results in somewhat less interaction. (Perhaps short-circuited feed-points also reduce interactions of traditional Yagis?)

System interactions degrade minor lobes of the non-targeted areas of the sky much more than the main beams, reducing QRM and QRN rejection.

Current-tapered short stacks (1/2 λ spacing) tolerate collocation somewhat better than tall stacks of 3/4 λ spacing.

The collocated stack impairs the single Yagi more than the single Yagi impairs the stack.

Separating the single Yagi and the stack by at least 1/2 λ keeps overall impairments to median gain relatively low, but some spot impairments of 7 dB can occur.

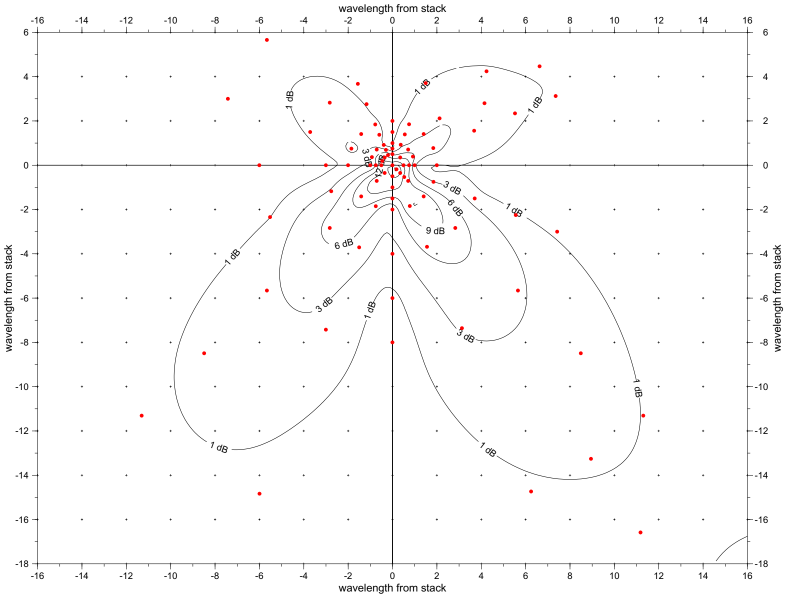
Separated systems

One may have more freedom to choose an appropriate height if the single Yagi is placed on a different tower. Those fortunate contesters with adequate space for multiple towers confront this question: "How close is too close?"

Let's begin to explore the answer by considering a stack and a single Yagi pointing toward azimuths differing by 90°. A short stack of two Yagis at 1/2 and 1 λ employs that OWA 6 element design which we have used to date in this article series. The single Yagi is of identical design.

Figure 1 maps out impairment as a function of relative antenna position. For this figure, the coordinate system originates at the stack. Since we showed in Table 3 that the single Yagi's pattern exhibits greater sensitivity to impairment from the stack, here the stack is not driven and its feed-points are shorted. The single Yagi stands 3/4 λ above ground. The single Yagi's main beam points up to the top of the map, and the stack points to the right. The models set the target zone as 50° wide in azimuth and ranging from 3 to 24° in elevation.

The tables in the previous sections summarized many views of impair-



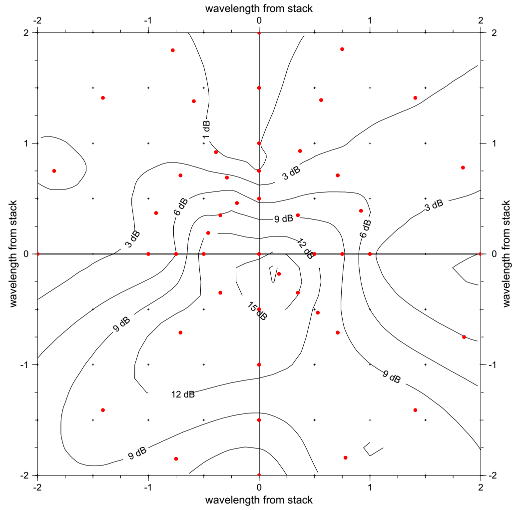


Figure 1—Map of impairment to the pattern of a single Yagi caused by a nearby two Yagi stack on the same band. The stack, two six element OWA 20 meter Yagis on 48 foot booms at heights of 1/2 and 1 λ, stands at the origin of the map and points to the right. It is not fed and has its feed-points shorted. The single Yagi (same type, mounted 3/4 λ high) points to the top of the map. The contours indicate the worst increase of gain outside the single Yagi's target zone as the location of the single Yagi relative to the stack is varied. The lower part of the figure zooms in to the locations immediately surrounding the stack.

Table 3

Impairments caused by the short stack to a single Yagi collocated on the same tower. The stack is unfed and its feed-points shorted. Yagi design and orientation otherwise are identical to Table 2. The table entries represent change in gain compared to a single Yagi at the indicated height but no stack present. The target zone for the single Yagi is 50° wide in azimuth and 2-24° elevation for heights of 3/4 λ and above. Below 3/4 λ height the elevation range narrows at the bottom to 6-24° in steps of 1° for each 1/8 λ decrease in height. Above 1 1/8 λ the elevation range narrows at the top to 2-18° in steps of 2° for each 1/8 λ.

single Yagi height	*change in target median gain (dB)*	*change in target minimum gain (dB)*	*largest decrease in target gain (dB)*	*largest increase in target gain (dB)*	*change in non-target median gain (dB)*	*change in worst non-target lobe gain (dB) (location if changed)*	*largest decrease in non-target gain (dB)*	*largest increase inin non-target gain (dB)*	*change % sky below -15 dBi*
1 1/2 λ	-0.05	-0.56	-0.56	+0.05	+0.23	+0.56 az 97° el 10°	-7.34	+6.91	-8.3%
1 3/8 λ	-0.11	-1.18	-1.18	+0.09	+0.84	+1.24 az 97° el 11°	-7.57	+9.31	-15.5%
1 1/4 λ	-0.26	-1.71	-1.80	+0.02	+3.01	+2.14 az 97° el 11°	-6.84	+14.84	-18.4%
1 1/8λ	-1.60	-3.43	-3.44	-0.99	+6.61	+7.36 az 52° el 12°	-4.34	+21.89	-20.9%
1-1/16 λ	-3.81	-5.41	-6.09	-2.57	+9.40	+9.64 az 53° el 12°	-6.78	+24.06	-24.1%
1 λ			— collides with top Yagi in stack —						
7/8 λ	-1.56	-2.81	-2.82	-1.02	+6.07	+8.02 az 51° el 12°	-6.39	+22.66	-20.7%
3/4 λ	-0.50	-1.53	-1.54	-0.09	+3.21	+3.87 az 234° el 15°	-9.01	+18.54	-14.9%
5/8 λ	-1.61	-2.75	-2.84	-0.99	+6.02	+6.74 az 52° el 23°	-4.43	+20.13	-18.0%
1/2 λ			— collides with bottom Yagi in stack —						
3/8 λ	-1.63	-2.69	-2.74	-1.06	+5.55	+7.62 az 50° el 27°	-6.87	+20.36	-15.5?
1/4 λ	-0.39	-0.96	-1.08	-0.02	+2.55	+1.52 az 97° el 35°	-6.28	+13.96	-14.0%

ments: reduction to median gain, worst minor lobes, spot increases and decreases in gain, etc. We saw that all the impairments outside the target zone varied together in a coordinated way. For this figure I have mapped the worst increase in spot gain outside the target zone as an indicator of relative impairment. Table 4, found on the *NCJ* Web site, summarizes all the impairment values at the locations indicated by a round dot on the map. I initially choose locations to develop an overall impression of the variation in impairments, and then run the models and meta-tools on additional spots needed to firm up the contours—about 80 spots in total.

The contour marked "1 dB" represents trivial impairments of no operational significance. Along the locations on this contour, the maximum increase in spot gain outside of the target zone for the single Yagi was 1 dB. Median gain, both outside the target zone and within the target zone, was unchanged. Within the target zone no disturbance of gain occurred.

Along the 3 dB contour, the pattern of the single Yagi varied slightly outside the target zone. Some spots improved by as much as 2 or 3 dB (i.e., lower gain), but these variations averaged out so that, as a whole, the entire non-targeted region saw its median gain change by 0.1 dB or less. No change in pattern occurred in the target zone. A spot increase of 3 dB in a specific direction towards QRM or QRN has almost no operational significance.

At the 6 dB contour pattern variations become more pronounced. The unused stack causes gains in the non-targeted regions to fluctuate both up and down

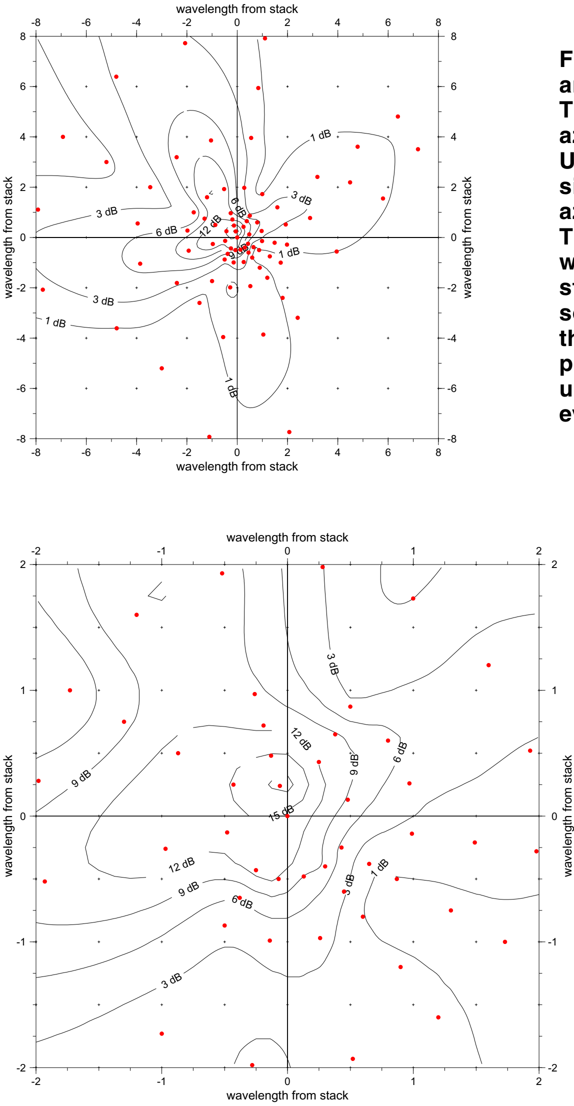


Figure 2—Same antennas as Figure 1. The stack points to 30° azimuth (Europe from the USA west coast). The single Yagi points to 120° azimuth (South America). The map shows that, when the single Yagi stands to the east-southeast of the stack, the impairment to its pattern caused by the unfed stack are minimal even at close spacings.

by 6 dB. Where the single Yagi, by itself, left 25% of the sky quiet with gains below –15 dBi, the unused stack has reduced that quiet sky to around 20%. Overall median gain in the non-target zone has started to creep up. The main beam remains unaffected; it varies an insignificant 0.1 dB in the target zone.

The 9 dB contour continues this trend. Quiet sky decreases below 20% as minor lobes fill in. Fractional dB variations in the main lobe appear at this level. The 12 dB contour encloses the region where minor lobes can reach or exceed 0 dBi. This area extends up to separations of about 1 λ. To provide greater clarity, the lower part of the figure zooms in to this region.

The irregularity of these maps initially surprised me. Depending on direction between the two antenna systems, one could be as close as 1 λ separation with no interaction. In a different direction one must go out 17 λ to eliminate interactions!

At a gross level the relative orientation of the antennas explains much of the variation. Along the +*y* axis the single Yagi faces away from the stack, and the stack points perpendicularly away from the single Yagi. This narrow corridor allows the closest separations for a given amount of impairment. In the upper left quadrant, the stack lies behind but to the right of the single Yagi. WFigure 2—Same antennas as Figure 1. The stack points to 30° azimuth (Europe from the USA west coast). The single Yagi points to 120° azimuth (South America). The map shows that, when the single Yagi stands to the east-southeast of the stack, the impairment to its pattern caused by the unfed stack are minimal even at close spacings.

While one must go as much as 5 λ to get to the 1 dB (no interaction) contour, the 3 dB contour requires separations of just over 1 λ at worst. In contrast, the lower right quadrant places the stack forward and left of the single Yagi. The single Yagi illuminates the stack with part of its forward main beam and the stack's Yagis (which point to the right) have some parasitic receiving gain in that direction.

Note also the dimples in the pattern where the direction of separation lies exactly at right angles to one of the two antenna systems—obvious zones in which to place the single Yagi in order to minimize interaction.

At separations of less than 2 λ this gross pattern twists and fluctuates somewhat irregularly. I suspect this is a result of near field interactions between the individual 18 elements of these 3 Yagis.

I expect the values and contours will shift somewhat if one substitutes Yagis with narrower or wider main beams or changes the heights of the Yagis. But regions relatively insensitive to interactions should occur in the same areas.

Apply impairment maps

Let's now apply this impairment map to a specific station design. Assume that the station is located near the west coast of the USA, where Europe and South America lie on nearly perpendicular azimuths. Figure 2 reorients Figure 1, rotating Figure 1 so that the stack points to Europe at 30° azimuth and flipping the pattern along the boom of the stack so that the single Yagi points to South America at 150°. If permitted by the layout of the property, the single Yagi should be located east-southeast of the stack, where even small separations result in little disruption to the antennas' patterns.

But what if the stack or single Yagi rotates? In that case the antenna systems do not necessarily point at right angles. The next part will show you how to locate rotating antenna systems to minimize interactions. In the meantime you can check the *NCJ* Web site for additional interaction maps that cover other relative orientations of these antenna systems' azimuths, the corresponding tables of impairment values, and associated sky hemisphere pattern maps. We will also examine cross-band interactions at odd harmonic multiples, using 15 meters and 40 meters to illustrate problems and how to avoid them. Again, the thoughtful choice of antenna locations around the station site will minimize interactions.

Errata and miscellany

Bob, N2RM, dropped me an e-mail message describing recent work at his station. His team constructed a 3 Yagi short stack (1/2 λ spacing) on 20 meters but left their original 2 Yagi tall stack (3/4 λ) up on another tower. On the air comparisons confirm the reduction in QRM from minor lobes described in Part 4. Bob's systems do not use current tapering.

A few errors crept into the paper publication of tables and figures in Part 4. Bits and pieces of the column headings in the tables did not line up properly, and two captions were interchanged. Download Part 4 from the *NCJ* Web site to see the correct tables, captions, and full-color figures.

The Web site also updates meta-tools *NouTrim.awk* and *AEGBin.awk* to correct a bug when target zones #1 and #2 are identical. A minor improvement to *NouDifference.bat* assigns a more logical filename to the file containing the sky hemisphere difference map. You will also find there an example of a GMT batch file to generate interaction maps such as Figure 1 from a table of data points.

Notes:

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[2] E. Scace, K3NA; "Antenna Interactions—Part 1: Stop Squinting! Get the Big Picture", *National Contest Journal*, 2003 Jul/Aug, pp 19-23.

[3] E. Scace, K3NA; "Antenna Interactions—Part 2: Twisting Stacks", *National Contest Journal*, 2003 Sep/Oct, pp 3-8.

[4] E. Scace, K3NA; "Antenna Interactions—Part 3: When Good Aluminum Goes Bad", *National Contest Journal*, 2003 Nov/Dec, pp 20-23.

[5] E. Scace, K3NA; "Antenna Interactions—Part 4: Cleaning Up Stacked Yagis with Current Tapers", *National Contest Journal,* 2004 Jan/Feb, pp 11-15.

NCJ