Antenna Interactions—Part 7
Antennas Pointing in Opposite Directions

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

Part 2 applied those meta-tools to twisted stacked Yagis where the antennas point in different directions, identifying some problem situations that contesters may encounter.[2]

Part 3 examined self-interactions of unused antennas within a stack, applying a new meta-tool to compare complete sky-hemisphere patterns. This part gave examples of siting problems in the design of a contesting station antenna farm, but did not fully explore siting issues.[3]

Part 4 introduced current tapering to clean up stack patterns.[4]

Part 5 identified impairments by identical antennas in the near field located on the same tower, or turned 90° on a separate tower.[5]

Part 6 described impairments by identical antennas in the near field on separate towers, when both antenna systems point in the same direction.[6]

In this part we look at identical antennas in the near field pointing in opposite directions.

Opposite Azimuths, Separate Towers

We continue to examine scenarios involving a short stack of 6-element 20m OWA Yagis, mounted at heights of ½ and 1λ. A third, identical Yagi stands ¾ λ above ground on a separate tower; we will refer to this as the "multiplier Yagi."

Part 5 of this series examined the scenario when the multiplier Yagi pointed to an azimuth at right angles to the stack's azimuth. Part 6 examined the case when both the stack and the multiplier Yagi point to the same azimuth. Today we look at the situation where the multiplier Yagi points in the opposite direction.

Having examined these three scenarios, we can make some recommendations about locating and using two towers with rotating Yagi systems on the same band.

Multiplier Yagi fed

We start by examining impairments to the pattern of the multiplier Yagi caused by the unused stack. The feedpoints of the stack's Yagis are short-circuited.

By itself, this multiplier Yagi's peak gain of 14.6dBi occurs at 17° elevation. The main beam's –3dB points stand ±28° to the left and right, and at 8 and 28° elevation. These –3dB points form the target zone for this analysis.

To identify the minor lobes, a range of ±51° in azimuth and 3 to 36° in elevation (representing the –11dB points on the main beam) was excluded from the non-target zone statistics. This exclusion prevented the sides of the main beam from obscuring information about the behavior of the pattern outside the main beam.

Table 1 summarizes pattern parameters and impairments as a function of relative location between these two antenna systems. The first row gives performance parameters for an isolated multiplier Yagi (i.e., no stack present) for comparison. The columns in this table represent, from left to right:

- Location of the multiplier antenna relative to the stack; e.g., 1 at 0° means the multiplier antenna stands one wavelength in front of the stack. The stack Yagis always point to 0° azimuth. The multiplier Yagi always points to 180°.
- Peak gain of the multiplier antenna, its azimuth and elevation, and the impairment to peak gain (change in peak gain caused by the presence of the unused stack).
- Median gain over the target zone, and the impairment to median gain.
- Minimum gain within the target zone, and the impairment to that minimum gain. Since no antenna fills a target zone uniformly, we want to know if impairments exist to the least well-served part of the target.
- Largest spot increase in gain, and largest spot decrease in gain, within the target zone. "Spot gain" refers to the gain in a specific direction (azimuth and elevation). A significant change in the gain in any one direction would be an undesirable interaction, even if the overall pattern averaged out to the same level of gain.
- Median gain outside of the main beam, and impairment to that median gain. A well-designed antenna has little sensitivity outside of its main beam; any increase in median gain indicates impaired performance. An entry of "floor" here means the median gain is less than the floor threshold of –15dBi.
- Worst (highest gain) minor lobe outside the main beam, its location, and the impairment (increase in gain of the worst minor lobe).
- Largest spot increase in gain, and largest spot decrease in gain, outside the main beam.
- Portion of the sky hemisphere with gain of <–15dBi (quiet regions of reduced QRM and QRN), and impairment to that portion.
- Feedpoint impedance.

Multiplier Yagi Impairment Overview

In the previous parts of this series, we examined three different, increasingly strict, thresholds for tolerable impairments between a stack and a multiplier antenna:

- No impairment within the target zone exceeding 1dB, but accept any degree of impairment outside the main beam.
- No impairment to the median gain outside the mean beam exceeding 1dB, and no variation in spot gain by more than 6dB (an S unit).
- No variation in spot gain at any point in the pattern exceeding 1dB.

As in other configurations, study of Table 1 reveals that all impairments vary

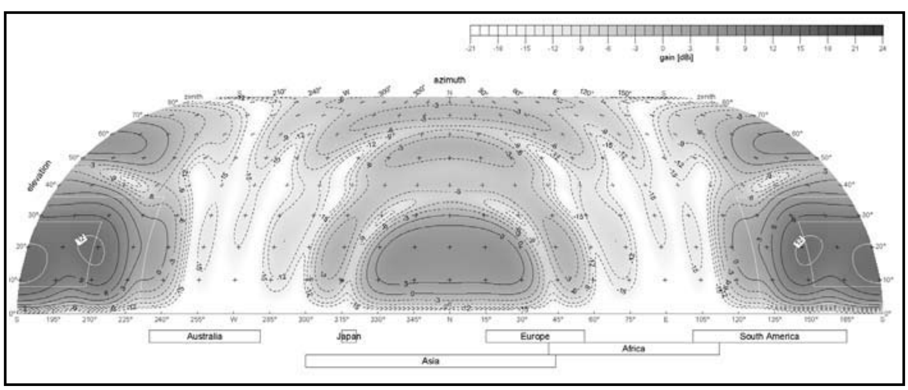


Figure 1—Gain pattern of the multiplier Yagi when it stands 4λ directly in front of the stack. The stack's Yagis point to 0° azimuth; the multiplier Yagi points to 180°. Parasitic re-radiation by the stack modulates the Yagi's pattern with a rippled pattern of constructive and destructive interference, and adds a substantial rear lobe.

Table 1

Performance parameters for the multiplier Yagi and impairments caused by a nearby 2-Yagi stack. The multiplier Yagi points toward 0° azimuth. The stack points 180°.

Yagi loc		target #1									non-target									feedpoint
dist	dir	peak gain			median gain		minimum gain		largest		median gain		worst minor lobe			largest		%sky <-15 dBi		
λ	°	dBi	location	delta	dBi	delta	dBi	delta	decr	incr	dBi	delta	dBi	location	delta	decr	incr		change	impedance
no stack		14.60	az 180° el 17°		12.66		8.84				-9.78		3.49	az 180° el 54°				25.0%		30.0 -j10.4
0.0	0°	10.26	az 180° el 21°	-4.34	8.53	-4.13	2.79	-6.05	-6.55	-1.47	-5.18	4.60	9.25	az 0° el 13°	5.76	-7.14	21.27	10.3%	-14.7%	63.4 +j42.3
0.5	0°	12.33	az 179° el 13°	-2.27	8.21	-4.45	2.46	-6.38	-8.04	-1.06	-7.57	2.21	12.33	az 0° el 13°	8.84	-13.39	19.81	17.4%	-7.6%	234 -j157
1.0	0°	13.05	az 179° el 13°	-1.55	8.14	-4.52	1.58	-7.26	-7.91	-0.11	-4.46	5.32	11.72	az 0° el 12°	8.23	-10.91	19.60	11.7%	-13.3%	119 -j107
2.0	0°	11.90	az 179° el 13°	-2.70	8.21	-4.45	3.86	-4.98	-5.57	-1.38	-5.24	4.54	7.79	az 0° el 12°	4.30	-8.96	17.42	19.8%	-5.2%	36.2 -j10.0
4.0	0°	13.18	az 179° el 13°	-1.42	11.43	-1.23	7.14	-1.70	-2.97	1.37	-7.51	2.27	5.75	az 342° el 17°	2.26	-8.54	11.51	19.3%	-5.7%	27.4 -j 6.2
8.0	0°	13.95	az 195° el 19°	-0.65	12.83	0.17	8.72	-0.12	-0.92	0.78	-9.85	-0.07	3.73	az 180° el 51°	0.24	-10.49	7.10	23.6%	-1.4%	29.3 -j10.5
16.0	0°	14.72	az 181° el 18°	0.12	12.70	0.04	8.79	-0.05	-0.24	0.23	-9.73	0.05	3.58	az 181° el 55°	0.09	-3.74	2.83	24.6%	-0.4%	29.9 -j10.5
28.0	0°	14.60	az 179° el 16°	0.00	12.68	0.02	8.78	-0.06	-0.09	0.08	-9.72	0.06	3.50	az 180° el 55°	0.01	-1.16	1.07	24.7%	-0.3%	30.0 -j10.4
32.0	0°	14.55	az 179° el 16°	-0.05	12.67	0.01	8.83	-0.01	-0.06	0.07	-9.74	0.04	3.49	az 180° el 53°	0.00	-0.89	0.84	24.8%	-0.2%	30.0 -j10.4
0.5	30°	11.73	az 159° el 15°	-2.87	7.90	-4.76	-2.13	-10.97	-13.30	0.36	-6.55	3.23	9.86	az 30° el 15°	6.37	-14.67	16.76	17.8%	-7.2%	55.5 +j55.6
1.0	30°	13.43	az 207° el 17°	-1.17	9.97	-2.69	5.64	-3.20	-6.01	1.96	-7.10	2.68	9.60	az 23° el 16°	6.11	-6.80	15.57	14.0%	-11.0%	37.6 +j 3.8
2.0	30°	15.78	az 194° el 17°	1.18	11.68	-0.98	6.17	-2.67	-3.08	2.24	-8.65	1.13	6.20	az 7° el 17°	2.71	-9.48	11.67	21.9%	-3.1%	30.0 -j 6.9
4.0	30°	15.73	az 183° el 16°	1.13	12.32	-0.34	7.78	-1.06	-1.55	1.30	-9.47	0.31	4.49	az 178° el 52°	1.00	-10.63	8.13	24.1%	-0.9%	29.5 -j 9.7
8.0	30°	14.85	az 186° el 17°	0.25	12.58	-0.08	8.91	0.07	-0.50	0.47	-9.72	0.06	3.85	az 180° el 54°	0.36	-7.20	3.94	24.5%	-0.5%	29.9 -j10.4
16.0	30°	14.71	az 181° el 17°	0.11	12.68	0.02	8.72	-0.12	-0.14	0.14	-9.72	0.06	3.59	az 180° el 54°	0.10	-1.55	1.32	24.7%	-0.3%	30.0 -j10.4
24.0	30°	14.65	az 178° el 17°	0.05	12.67	0.01	8.62	-0.22	-0.06	0.06	-9.75	0.03	3.53	az 180° el 54°	0.04	-0.69	0.64	24.7%	-0.3%	30.0 -j10.4
0.5	60°	12.50	az 206° el 17°	-2.10	9.94	-2.72	5.77	-3.07	-5.94	0.86	-6.93	2.85	8.68	az 5° el 15°	5.19	-9.00	14.99	11.5%	-13.5%	19.8 -j 9.2
1.0	60°	15.03	az 192° el 17°	0.43	12.43	-0.23	7.56	-1.28	-1.74	1.42	-10.21	-0.43	4.14	az 128° el 17°	0.65	-10.53	7.38	25.3%	0.3%	29.2 -j11.0
2.0	60°	14.99	az 175° el 17°	0.39	12.70	0.04	8.29	-0.55	-0.58	0.57	-9.76	0.02	3.53	az 128° el 17°	0.04	-2.82	2.32	24.4%	-0.6%	30.0 -j10.5
4.0	60°	14.74	az 177° el 17°	0.14	12.67	0.01	8.86	0.02	-0.20	0.19	-9.73	0.05	3.67	az 181° el 54°	0.18	-0.74	0.79	25.0%	0.0%	30.0 -j10.4
8.0	60°	14.63	az 178° el 17°	0.03	12.68	0.02	8.81	-0.03	-0.06	0.06	-9.77	0.01	3.51	az 183° el 54°	0.02	-0.26	0.24	24.9%	-0.1%	30.0 -j10.4
16.0	60°	14.60	az 182° el 17°	0.00	12.66	0.00	8.85	0.01	-0.02	0.02	-9.76	0.02	3.49	az 178° el 54°	0.00	-0.06	0.07	25.0%	0.0%	30.0 -j10.4
0.5	90°	12.79	az 196° el 17°	-1.81	11.86	-0.80	8.98	0.14	-2.23	0.69	-8.78	1.00	6.00	az 231° el 17°	2.51	-6.56	10.75	24.4%	-0.6%	36.2 -j 9.7
1.0	90°	14.77	az 176° el 17°	0.17	12.66	0.00	8.54	-0.30	-0.40	0.35	-9.77	0.01	3.73	az 231° el 17°	0.24	-4.32	2.92	24.1%	-0.9%	30.0 -j10.4
1.5	90°	14.62	az 182° el 17°	0.02	12.65	-0.01	8.75	-0.09	-0.12	0.12	-9.76	0.02	3.47	az 178° el 54°	-0.02	-1.52	1.53	24.5%	-0.5%	30.0 -j10.4
2.0	90°	14.60	az 178° el 17°	0.00	12.67	0.01	8.76	-0.08	-0.08	0.08	-9.74	0.04	3.56	az 180° el 54°	0.07	-0.85	0.79	24.8%	-0.2%	30.0 -j10.4
2.5	90°	14.62	az 181° el 17°	0.02	12.66	0.00	8.85	0.01	-0.04	0.05	-9.73	0.05	3.46	az 181° el 54°	-0.03	-0.52	0.52	24.7%	-0.3%	30.0 -j10.4
0.5	120°	12.50	az 154° el 17°	-2.10	9.94	-2.72	5.77	-3.07	-5.94	0.86	-6.93	2.85	8.68	az 355° el 15°	5.19	-9.00	14.99	11.5%	-13.5%	19.8 -j 9.2
1.0	120°	15.03	az 168° el 17°	0.43	12.43	-0.23	7.56	-1.28	-1.73	1.42	-10.21	-0.43	4.14	az 231° el 17°	0.65	-10.53	7.38	25.3%	0.3%	29.2 -j11.0
2.0	120°	14.99	az 184° el 17°	0.39	12.70	0.04	8.29	-0.55	-0.58	0.57	-9.76	0.02	3.53	az 231° el 17°	0.04	-2.82	2.32	24.4%	-0.6%	30.0 -j10.5
4.0	120°	14.74	az 182° el 17°	0.14	12.67	0.01	8.86	0.02	-0.19	0.19	-8.73	1.05	3.67	az 178° el 54°	0.18	-0.72	0.79	25.0%	0.0%	30.0 -j10.4
8.0	120°	14.63	az 182° el 17°	0.03	12.67	0.01	8.81	-0.03	-0.06	0.05	-9.77	0.01	3.51	az 178° el 54°	0.02	-0.24	0.24	24.9%	-0.1%	30.0 -j10.4
16.0	120°	14.60	az 182° el 17°	0.00	12.66	0.00	8.82	-0.02	-0.02	0.02	-9.76	0.02	3.49	az 181° el 54°	0.00	-0.07	0.07	25.0%	0.0%	30.0 -j10.4
0.5	150°	14.52	az 184° el 17°	-0.08	12.62	-0.04	8.11	-0.73	-0.75	0.56	-11.68	-1.90	4.43	az 231° el 17°	0.94	-10.63	7.88	31.5%	6.5%	31.9 -j10.4
1.0	150°	14.51	az 183° el 17°	-0.09	12.59	-0.07	8.62	-0.22	-0.42	0.33	-10.53	-0.75	4.22	az 128° el 17°	0.73	-5.92	5.35	23.4%	-1.6%	30.0 -j10.6
2.0	150°	15.78	az 165° el 17°	1.18	11.68	-0.98	6.17	-2.67	-3.08	2.24	-8.64	1.14	6.20	az 352° el 17°	2.71	-9.48	11.67	21.9%	-3.1%	30.0 -j 6.9
4.0	150°	15.73	az 176° el 16°	1.13	12.32	-0.34	7.78	-1.06	-1.55	1.30	-9.47	0.31	4.49	az 183° el 52°	1.00	-10.63	8.13	24.1%	-0.9%	29.5 -j 9.7
8.0	150°	14.85	az 173° el 17°	0.25	12.58	-0.08	8.91	0.07	-0.50	0.47	-9.72	0.06	3.85	az 180° el 54°	0.36	-7.19	3.94	24.5%	-0.5%	29.9 -j10.4
16.0	150°	14.71	az 178° el 17°	0.11	12.68	0.02	8.73	-0.11	-0.14	0.14	-9.73	0.05	3.59	az 180° el 54°	0.10	-1.55	1.32	24.7%	-0.3%	30.0 -j10.4
24.0	150°	14.65	az 181° el 17°	0.05	12.67	0.01	8.82	-0.02	-0.07	0.07	-9.75	0.03	3.53	az 180° el 54°	0.04	-0.69	0.64	24.7%	-0.3%	30.0 -j10.4
0.5	180°	14.77	az 181° el 17°	0.17	12.80	0.14	8.94	0.10	0.07	0.21	-12.21	-2.43	3.18	az 180° el 55°	-0.31	-10.43	5.52	30.5%	5.5%	31.0 -j11.1
1.0	180°	14.82	az 181° el 17°	0.22	12.78	0.12	8.63	-0.21	-0.21	0.27	-10.07	-0.29	3.82	az 180° el 54°	0.33	-7.05	5.47	24.0%	-1.0%	29.9 -j10.7
2.0	180°	14.63	az 181° el 17°	0.03	12.56	-0.10	8.62	-0.22	-0.28	0.16	-10.23	-0.45	4.12	az 231° el 17°	0.63	-4.98	4.89	23.5%	-1.5%	30.1 -j10.5
4.0	180°	14.48	az 181° el 17°	-0.12	12.64	-0.02	8.88	0.04	-0.14	0.22	-9.69	0.09	3.67	az 180° el 55°	0.18	-2.57	2.34	23.8%	-1.2%	30.0 -j10.4
8.0	180°	14.59	az 181° el 17°	-0.01	12.68	0.02	8.84	0.00	-0.06	0.06	-9.74	0.04	3.47	az 180° el 55°	-0.02	-0.85	0.97	24.7%	-0.3%	30.0 -j10.4

in a coordinated fashion, rising and falling together. While impairments to the main beam rapidly dwindle in significance as spacing between the antenna systems increases, the antenna pattern outside the main beam can remain impaired at greater distances.

The extreme example occurs when the multiplier Yagi stands in front of, and therefore points towards, the stack. The stack, illuminated by radiation from the multiplier Yagi, re-radiates parasitically, producing a classic interference pattern. In this alignment one must separate these systems by about 6λ before impairments to the main beam fall below 1dB, our first design threshold.

Figure 1 shows the pattern impairments in this alignment at a separation of 4λ. Note the substantial rear lobe (+5.8dBi) caused by re-radiation off the stack. To meet our second design criterion requires about 12λ separation. The most stringent design goal requires 31 λ separation, the largest identified to date in this series.

In contrast, when the multiplier Yagi stands off to the side of the stack, at right angles to the stack's azimuth, just over 2λ separation achieves our most stringent third design criterion.

Figure 2 maps contours of this spot variation in the pattern as the site of the multiplier Yagi moves around the center of the stack. Three zones allow significantly closer spacing with no pattern impairment: off to the left or right of the stack, and behind the stack.

Beam Shifts In Azimuth

The stack, when standing ½ to 1 λ away from the multiplier Yagi and 30-60° to the left or right of it, sucks the multiplier Yagi's main beam away from its intended direction. This shift is toward the stack, and can exceed 25° in azimuth. The multiplier Yagi's signal in the intended direction (along the axis of the boom) drops about –4dB. See Figure 3.

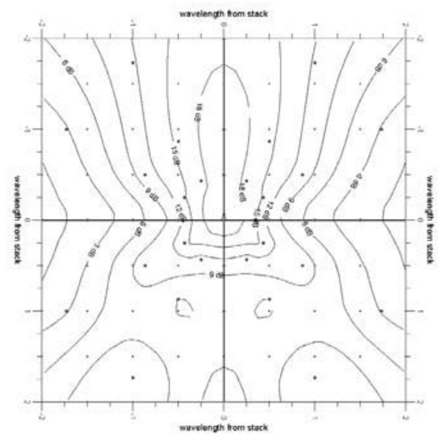
Improvement To The Multiplier Yagi

Table 1 shows something else unique to antennas pointing in opposite directions. When the multiplier Yagi stands ½λ behind the stack, the multiplier Yagi's pattern improves! Main beam gain increases by a fraction of a dB, which is not operationally significant. The rear lobes decline by over –10dB.

Further iterations indicate the pattern improvements hold over a range of locations for these OWA antennas. The tiny boost to the multiplier Yagi's main beam peaks when the reflector lies in the same vertical plane as the reflectors for the stack.

The best rear lobe reductions occur when the multiplier Yagi's reflector lies in the same vertical plane as the stack's driven elements; however, this location seems a bit too sensitive as any further displacement of the multiplier Yagi underneath the stack triggers a rapid growth in the rear lobe and reduced forward gain. Placing the multiplier Yagi's reflector midway between the vertical planes containing the stack's reflectors and driven elements represents a good compromise, with rear lobes reduced by over –12dB. The entire sky outside of the main beam becomes more than –3 dB quieter.

While intriguing, such an improvement is difficult to exploit. If these Yagis cantilever fore and aft from a single tower, guy wires probably would restrict the system from rotation. For stations



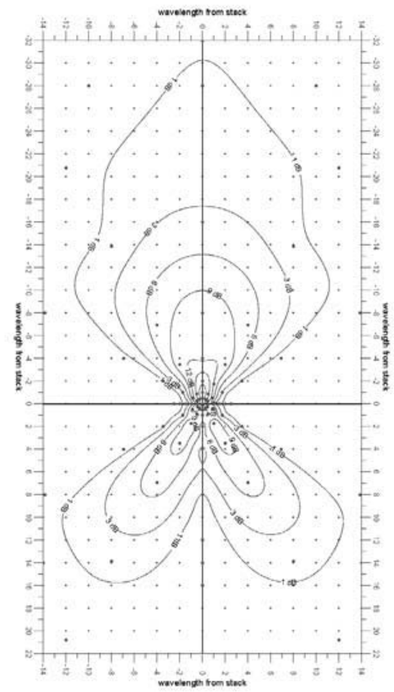
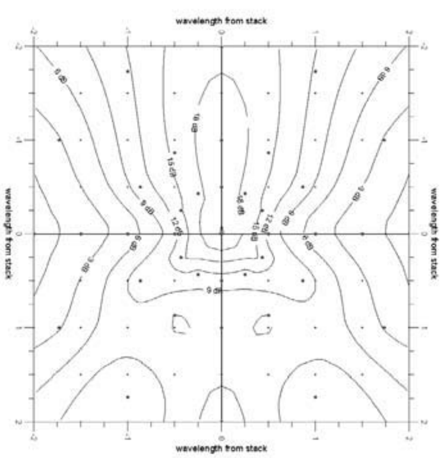


Figure 2—Maximum absolute variations in spot gain in any direction for the multiplier Yagi due to the presence of the stack. The stack stands at the origin of the coordinate system. Dots indicate calculated locations for the multiplier Yagi relative to the stack. The stack points up (0° azimuth); the multiplier antenna points down (180° azimuth).



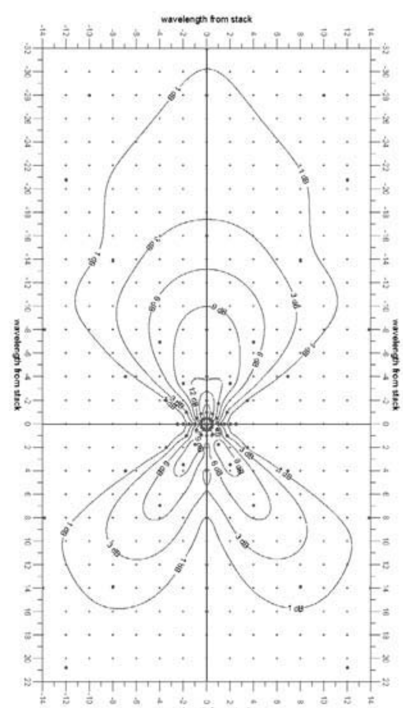


Figure 3—Gain pattern of the multiplier Yagi when it stands 1λ in front of, and 30° left or right of, the stack. The stack sucks the point of peak gain to shift 27° in azimuth off the intended direction (south) to 207°. The stack adds a large rear lobe, also shifted in azimuth by an equal amount.

Table 2

Performance parameters for the stack and impairments caused by a near-by multiplier Yagi. The stack's antennas point toward 0° azimuth. The multiplier Yagi points 180°. See text for explanation of column entries.

Yagi loc		target #1									non-target										
dist	dir	peak gain			median gain		minimum gain		largest		median gain		worst minor lobe			largest		% sky <-15dBi		feedpoint impedance	
λ	°	dBi	location	delta	dBi	delta	dBi	delta	decr	incr	dBi	delta	dBi	location	delta	decr	incr		delta	top	bottom
no mult		15.76	az 0° el 15°		13.87		10.09				floor		-4.88	az 0° el 48°				47.2%		26.7 -j 7.8	27.7 -j 8.1
0.0	0°	12.94	az 0° el 14°	-2.82	11.04	-2.83	6.25	-3.84	-4.20	-2.00	-5.72	9.28	6.60	az 181° el 65°	11.48	-8.96	21.60	8.3%	-38.9%	50.9 +j38.9	52.9 +j42.6
0.5	0°	13.23	az 0° el 13°	-2.53	10.29	-3.58	3.04	-7.05	-7.15	-1.65	-7.20	7.80	11.12	az 179° el 13°	16.00	-8.99	25.89	12.3%	-34.9%	226 -j137	232 -j125
1.0	0°	13.00	az 0° el 12°	-2.76	8.18	-5.69	-1.76	-11.85	-13.20	-1.50	-4.72	10.28	11.68	az 179° el 13°	16.56	-5.80	26.41	12.2%	-35.0%	108 -j96.4	99.5 -j91.0
2.0	0°	13.92	az 0° el 12°	-1.84	10.03	-3.84	6.30	-3.79	-5.57	-0.71	-6.21	8.79	7.75	az 180° el 14°	12.63	-5.86	22.52	16.2%	-31.0%	29.8 +j16.1	38.8 +j 7.9
4.0	0°	14.88	az 0° el 12°	-0.88	12.40	-1.47	8.76	-1.33	-2.53	1.69	-11.36	3.64	3.95	az 180° el 12°	8.83	-6.38	18.67	23.6%	-23.6%	23.1 -j 6.0	25.1 -j 2.4
8.0	0°	15.25	az 0° el 14°	-0.51	14.01	0.14	9.37	-0.72	-0.75	0.71	-14.66	0.34	-3.80	az 0° el 50°	1.08	-5.15	11.15	38.6%	-8.6%	26.4 -j 8.0	26.9 -j 8.1
16.0	0°	15.71	az 0° el 16°	-0.05	13.79	-0.08	10.07	-0.02	-0.20	0.19	floor	—	-4.73	az 59° el 15°	0.15	-2.81	5.18	44.9%	-2.3%	26.7 -j 7.9	27.6 -j 8.1
28.0	0°	15.81	az 0° el 15°	0.05	13.86	-0.01	10.14	0.05	-0.07	0.07	floor	—	-4.85	az 0° el 49°	0.03	-1.16	2.02	46.8%	-0.4%	26.7 -j 7.8	27.7 -j 8.1
32.0	0°	15.76	az 0° el 14°	0.00	13.86	-0.01	10.07	-0.02	-0.05	0.05	floor	—	-4.83	az 0° el 48°	0.05	-1.08	1.55	47.0%	-0.2%	26.7 -j 7.8	27.7 -j 8.1
0.5	30°	12.66	az 345° el 14°	-3.10	10.11	-3.76	5.45	-4.64	-7.28	-0.71	-8.08	6.92	10.36	az 160° el 15°	15.24	-8.96	25.36	17.2%	-30.0%	48.3 +j54.1	46.3 +j55.2
1.0	30°	14.41	az 24° el 16°	-1.35	11.54	-2.33	6.87	-3.22	-5.27	2.20	-8.61	6.39	7.43	az 210° el 17°	12.31	-7.93	22.43	13.5%	-33.7%	33.2 +j 6.7	33.6 +j 4.5
2.0	30°	16.54	az 13° el 16°	0.78	13.26	-0.61	7.34	-2.75	-2.86	2.11	-11.76	3.24	4.00	az 196° el 18°	8.88	-7.59	19.00	22.7%	-24.5%	26.0 -j 4.0	28.5 -j 5.2
4.0	30°	16.65	az 3° el 15°	0.89	13.57	-0.30	8.84	-1.25	-1.32	1.16	-14.15	0.85	-0.80	az 185° el 16°	4.08	-6.58	14.20	36.0%	-11.2%	26.1 -j 7.6	27.2 -j 7.1
8.0	30°	15.88	az 6° el 15°	0.12	13.80	-0.07	9.84	-0.25	-0.40	0.40	floor	—	-4.29	az 7° el 49°	0.59	-4.34	7.03	44.0%	-3.2%	26.6 -j 7.9	27.6 -j 8.1
16.0	30°	15.83	az 2° el 15°	0.07	13.88	0.01	10.02	-0.07	-0.11	0.11	floor	—	-4.65	az 1° el 48°	0.23	-1.64	2.52	46.6%	-0.6%	26.7 -j 7.8	27.7 -j 8.1
24.0	30°	15.80	az 0° el 15°	0.04	13.88	0.01	10.06	-0.03	-0.05	0.05	floor	—	-4.79	az 358° el 48°	0.09	-0.86	1.23	47.2%	0.0%	26.7 -j 7.8	27.7 -j 8.1
0.5	60°	13.31	az 20° el 15°	-2.45	12.23	-1.64	9.19	-0.90	-3.70	0.35	-9.40	5.60	6.97	az 209° el 17°	11.85	-9.87	21.97	12.4%	-34.8%	15.6 -j 6.9	16.5 -j 7.2
1.0	60°	15.87	az 10° el 15°	0.11	13.69	-0.18	9.05	-1.04	-1.39	1.18	floor	—	-0.65	az 192° el 16°	4.23	-7.39	14.35	41.7%	-5.5%	25.9 -j 8.5	27.1 -j 8.7
2.0	60°	15.99	az 356° el 15°	0.23	13.83	-0.04	9.78	-0.31	-0.39	0.41	floor	—	-4.28	az 59° el 15°	0.60	-3.29	4.89	44.4%	-2.8%	26.7 -j 7.9	27.7 -j 8.1
4.0	60°	15.83	az 357° el 15°	0.07	13.84	-0.03	10.10	0.01	-0.12	0.12	floor	—	-4.68	az 4° el 48°	0.20	-1.19	1.35	47.1%	-0.1%	26.7 -j 7.8	27.7 -j 8.1
8.0	60°	15.77	az 358° el 15°	0.01	13.87	0.00	10.07	-0.02	-0.03	0.03	floor	—	-4.87	az 356° el 48°	0.01	-0.33	0.35	47.2%	0.0%	26.7 -j 7.8	27.7 -j 8.1
16.0	60°	15.76	az 358° el 15°	0.00	13.87	0.00	10.09	0.00	-0.01	0.01	floor	—	-4.87	az 1° el 48°	0.01	-0.09	0.10	47.3%	0.1%	26.7 -j 7.8	27.7 -j 8.1
0.5	90°	14.37	az 0° el 15°	-1.39	13.20	-0.67	10.03	-0.06	-1.77	0.40	-13.28	1.72	2.69	az 201° el 18°	7.57	-9.18	17.69	31.7%	-15.5%	31.6 -j 6.8	32.9 -j 6.6
1.0	90°	15.88	az 357° el 15°	0.12	13.85	-0.02	9.80	-0.29	-0.37	0.31	floor	—	-4.28	az 59° el 15°	0.60	-3.86	4.51	44.7%	-2.5%	26.7 -j 7.8	27.6 -j 8.0
1.5	90°	15.76	az 2° el 15°	0.00	13.86	-0.01	10.04	-0.05	-0.11	0.10	floor	—	-4.60	az 59° el 15°	0.28	-1.75	1.92	45.8%	-1.4%	26.7 -j 7.8	27.7 -j 8.1
2.0	90°	15.76	az 358° el 15°	0.00	13.87	0.00	10.05	-0.04	-0.07	0.07	floor	—	-4.71	az 59° el 15°	0.17	-1.45	1.50	46.9%	-0.3%	26.7 -j 7.8	27.7 -j 8.1
2.5	90°	15.77	az 0° el 15°	0.01	13.86	-0.01	10.09	0.00	-0.04	0.05	floor	—	-4.78	az 59° el 15°	0.10	-0.42	0.49	47.5%	0.3%	26.7 -j 7.8	27.7 -j 8.1
0.5	120°	13.31	az 340° el 15°	-2.45	12.23	-1.64	9.19	-0.90	-3.70	0.35	-9.40	5.60	6.97	az 152° el 17°	11.85	-9.87	21.97	12.4%	-34.8%	15.6 -j 6.9	16.5 -j 7.2
1.0	120°	15.87	az 350° el 15°	0.11	13.69	-0.18	9.05	-1.04	-1.38	1.18	floor	—	-0.65	az 168° el 16°	4.23	-7.39	14.35	41.7%	-5.5%	25.9 -j 8.5	27.1 -j 8.7
2.0	120°	15.99	az 3° el 15°	0.23	13.83	-0.04	9.78	-0.31	-0.40	0.41	floor	—	-4.30	az 300° el 15°	0.58	-3.29	4.89	44.4%	-2.8%	26.7 -j 7.9	27.7 -j 8.1
4.0	120°	15.83	az 2° el 15°	0.07	13.84	-0.03	10.10	0.01	-0.12	0.12	floor	—	-4.68	az 355° el 48°	0.20	-1.19	1.36	47.1%	-0.1%	26.7 -j 7.8	27.7 -j 8.1
8.0	120°	15.77	az 1° el 15°	0.01	13.87	0.00	10.07	-0.02	-0.03	0.03	floor	—	-0.05	az 3° el 48°	4.83	-0.33	0.35	47.2%	0.0%	26.7 -j 7.8	27.7 -j 8.1
16.0	120°	15.76	az 1° el 15°	0.00	13.87	0.00	10.09	0.00	-0.01	0.01	floor	—	-4.87	az 358° el 48°	0.01	-0.09	0.10	47.3%	0.1%	26.7 -j 7.8	27.7 -j 8.1
0.5	150°	15.56	az 2° el 15°	-0.20	13.70	-0.17	9.81	-0.28	-0.43	0.24	-12.90	2.10	-2.14	az 350° el 15°	2.74	-6.61	10.25	30.1%	-17.1%	27.3 -j 6.3	28.7 -j 6.2
0.75	150°	15.78	az 0° el 15°	0.02	13.87	0.00	9.97	-0.12	-0.15	0.12	floor	—	-4.43	az 59° el 15°	0.45	-2.07	2.06	51.2%	4.0%	26.7 -j 7.8	27.8 -j 8.0
1.0	150°	15.75	az 0° el 15°	-0.01	13.87	0.00	10.06	-0.03	-0.05	0.07	floor	—	-4.72	az 0° el 48°	0.16	-1.48	2.16	47.6%	0.4%	26.7 -j 7.8	27.7 -j 8.1
1.5	150°	15.75	az 0° el 15°	-0.01	13.87	0.00	10.08	-0.01	-0.04	0.06	floor	—	-4.76	az 0° el 48°	0.12	-1.52	1.97	46.0%	-1.2%	26.7 -j 7.8	27.7 -j 8.1
2.0	150°	15.64	az 346° el 16°	-0.12	13.24	-0.63	7.35	-2.74	-2.87	2.11	-11.76	3.24	4.00	az 163° el 18°	8.88	-7.59	19.00	22.6%	-24.6%	26.0 -j 4.0	28.5 -j 5.2
4.0	150°	16.65	az 356° el 15°	0.89	13.57	-0.30	8.85	-1.24	-1.31	1.15	-14.15	0.85	-0.80	az 174° el 16°	4.08	-6.58	14.20	36.0%	-11.2%	26.1 -j 7.6	27.2 -j 7.1
8.0	150°	15.88	az 353° el 15°	0.12	13.80	-0.07	9.84	-0.25	-0.40	0.40	floor	—	-4.29	az 352° el 49°	0.59	-4.34	7.03	44.0%	-3.2%	26.6 -j 7.9	27.6 -j 8.1
16.0	150°	15.83	az 357° el 15°	0.07	13.88	0.01	10.02	-0.07	-0.11	0.11	floor	—	-4.65	az 358° el 48°	0.23	-1.64	2.52	46.6%	-0.6%	26.7 -j 7.8	27.7 -j 8.1
24.0	150°	15.80	az 0° el 15°	0.04	13.88	0.01	10.06	-0.03	-0.05	0.50	floor	—	-4.79	az 1° el 48°	0.09	-0.86	1.23	47.2%	0.0%	26.7 -j 7.8	27.7 -j 8.1
0.5	180°	15.77	az 0° el 15°	0.01	13.86	-0.01	10.05	-0.04	-0.08	0.04	-14.74	0.26	-4.23	az 59° el 15°	0.65	-4.76	4.95	39.1%	-8.1%	27.6 -j 6.7	29.0 -j 6.8
1.0	180°	15.68	az 0° el 15°	-0.08	13.82	-0.05	10.05	-0.04	-0.08	0.03	floor	—	-4.20	az 0° el 49°	0.68	-5.49	4.03	43.9%	-3.3%	26.7 -j 7.9	27.7 -j 8.2
2.0	180°	15.73	az 0° el 15°	-0.03	13.87	0.00	10.11	0.02	-0.04	0.07	floor	—	-4.83	az 0° el 48°	0.05	-3.40	2.91	47.8%	0.6%	26.7 -j 7.8	27.7 -j 8.1
4.0	180°	15.77	az 0° el 15°	0.01	13.89	0.02	10.07	-0.02	-0.05	0.03	floor	—	-4.80	az 0° el 48°	0.08	-1.21	1.47	47.3%	0.1%	26.7 -j 7.8	27.7 -j 8.1
8.0	180°	15.76	az 0° el 15°	0.00	13.87	0.00	10.09	0.00	-0.01	0.02	floor	—	-4.93	az 0° el 48°	-0.05	-0.59	0.50	47.9%	0.7%	26.7 -j 7.8	27.7 -j 8.1

in northeast USA, a tower containing a stack fixed on Europe could add this rear-facing Yagi for domestic contesting or as a QRM-chaser.

Stack fed

Having examined impairments when feeding the multiplier Yagi, now reverse the roles and feed the stack. The multiplier Yagi's feedpoint is short-circuited.

In isolation the stack's peak gain of +15.76dBi occurs at 15° elevation. The main beam's –3dB points stand ±26° to the left and right, and at 7 and 25° elevation. These –3dB points form the target zone for this analysis.

To identify the minor lobes, a range of ±59° in azimuth and 1 to 38° in elevation (representing the –20dB points on the main beam) was excluded from the non-target zone statistics. This exclusion prevented the sides of the main beam from obscuring information about the behavior of the pattern outside the main beam.

Table 2 itemizes pattern impairments to the stack. The stack's pattern displays slightly less sensitivity to the presence of the multiplier Yagi in this orientation than vice versa. We find again that, when the antenna systems point towards each other, the most stringent impairment demand requires tremendous separation (over 32 λ). Little disruption to drivepoint impedance exists except for the closer spacings with the multiplier Yagi in front of the stack. An examination of the table also reveals a poorly sited, unused multiplier antenna can deviate the stack's main lobe as much as 24° off the intended azimuth.

Figure 4 maps out the worst impairment to the pattern of the stack as a function of the location of the multiplier antenna. The antennas show little interaction when placed off to the left or right. Another sweet spot exists where close spacing exhibits little pattern disruption: at around 1 λ and 150° behind and to the right (or, similarly, at 210° behind and to the left), the multiplier antenna barely disturbs the stack. These areas of minimum interaction are similar to those of Figure 2, allowing use of either antenna system.

Practical Applications

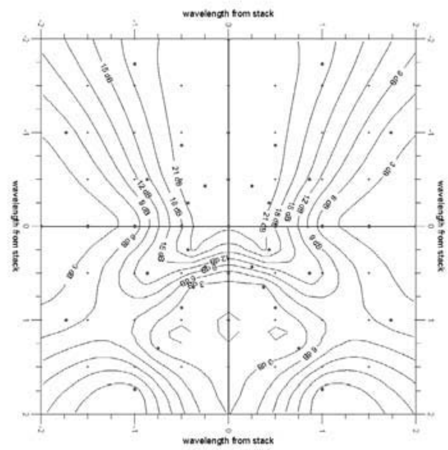
Let's now illustrate how the techniques illustrated in Parts 5–7 can be applied to typical station design problems, following these steps:

• Determine relative orientation(s) of the two antenna systems.

• Determine available separation space.

• Consult the tables and maps for the most similar orientation to identify likely regions of minimum interaction within the available separation space. Be sure to examine the interactions when each of the two antenna systems transmits.

• Run models to verify the expected level of interaction for the specific an-



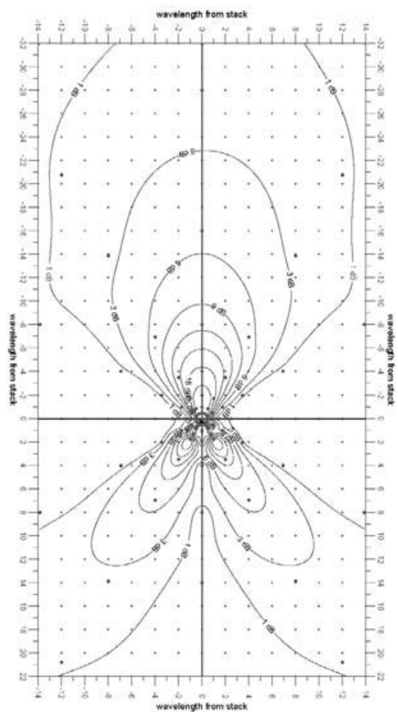


Figure 4—Maximum absolute variations in spot gain in any direction for the stack due to the presence of the multiplier Yagi. The stack stands at the origin of the coordinate system. Dots indicate calculated locations for the multiplier Yagi relative to the stack. The stack points up (0° azimuth); the multiplier antenna points down (180° azimuth).

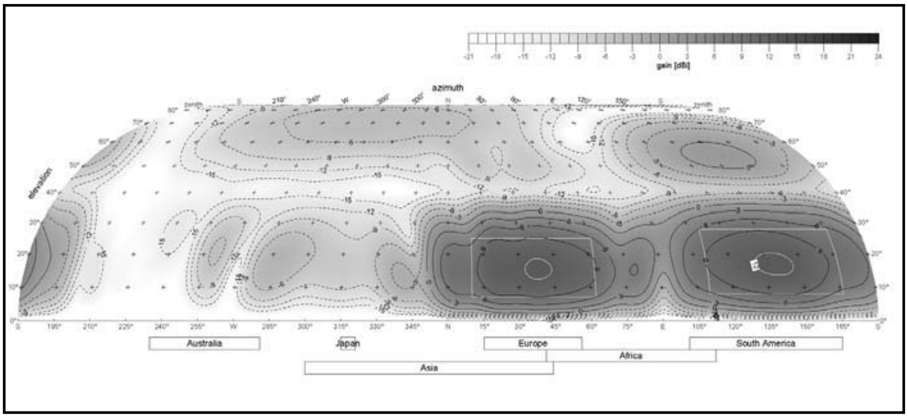


Figure 5—Austin, Texas station with 2-Yagi fixed stack on Europe and a fixed Yagi on South America. The feed system delivers specific current ratios to equalize the beams into both continents.

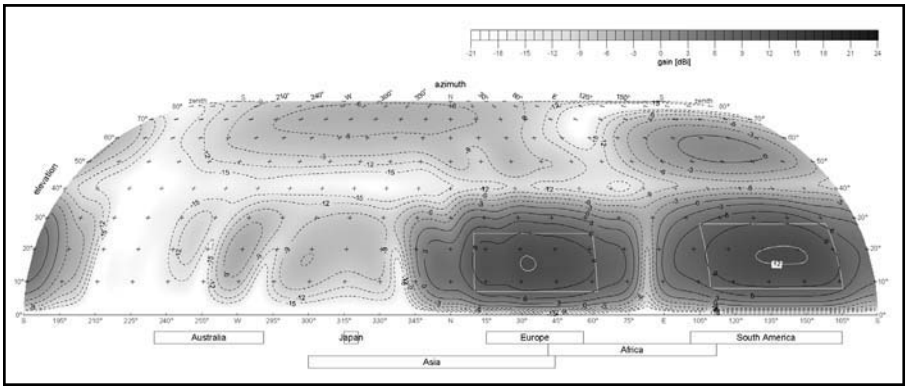


Figure 6—Same systems as Figure 5, with phase and current levels adjusted for cleanest patterns.

tennas, orientations, and spacing, iterating around the proposed location to check for sensitivity in position.

The last step is very important! The near field geometry can vary considerably from antenna to antenna; a 3-element Yagi, for example, likely will exhibit a different level of interactions than the 6-element owa designs used in this series. Real world orientations may be different from the general cases examined here. The charts and tables in these articles can point you in the general direction of candidate locations for reduced interaction—but you need to run some models with your specific locations and antennas to verify the candidate locations could provide reasonable results.

Fixed Stack And Fixed Single Yagi

Problem: A station in Austin, Texas includes a 20meter stack (6-element OWA Yagis at ½ and 1 λ height) fixed on Europe and a single 20 meter Yagi (6-element OWA at ¾ λ height) fixed on South America/Caribbean to minimize interactions. The site requires the two antenna systems to be within 200 feet (60 meters, or about 3 λ). Where should these antenna systems stand to minimize impairments?

An equidistant-azimuthal chart centered on Austin shows Europe to span 15–57° azimuth (centered on 36°). South America and the Caribbean cover 110–166° azimuth (centered on 138°). The two main beam bearings are 102° apart, so the antenna systems will point nearly at right angles. We should therefore use the data for antennas pointed at right angles.

Part 5 Figure 1 and the underlying model results show little effect on the single Yagi's pattern when it stands 3 λ away and 90° off to the side of the stack, and facing away from it. Calculations of the stack's pattern (not published in the paper edition of *NCJ*) also show a minimum in level of interaction at these locations. Let's adopt the convention of measuring distances relative to the stack. Since the stack points 36° toward Europe, our tentative location for the South American Yagi stands 200 feet away in the direction 126°, at 162 feet East, 118 feet South; this antenna points to 138° azimuth.

Model runs with this specific geometry confirm the lack of interaction between these systems. When feeding the South America/Caribbean Yagi, no part of the pattern deviates by more than ¼ dB due to the presence of the stack. When feeding the Europe stack, no part of the pattern deviates more than 0.9dB. The models confirm the suitability of the candidate sites.

Driving Both Systems Together

With little interaction between the systems individually, can we drive both together? Yes, with some minor interference between the patterns. One must divide the power carefully, however. Simply splitting currents equally between the two systems results in unequal beams; the South America beam peaks at 2½ dB more than the European beam. Applying equal currents to each of the three Yagis reverses the imbalance, with Europe peaking 3.3dB louder. The ratio 1.5:1:1 (South America to Europe-top to Europe-bottom) provides beams with equal peak gain. See Figure 5 for the resultant pattern.

We can reduce the interference between the two beams and reduce minor lobes by altering the phase relationship between the drive currents for the South America Yagi and the Europe stack. Feeding the South America system +135° in phase with a current ratio of 1.6:1:1 delivers a slightly cleaner pattern, with two clearly separated main

Table 3

Summary of impairments for a rotating Yagi located within 3 behind and to the side of a fixed 2-Yagi stack pointing to 36° azimuth. See text for detailed description of the table entries. Italicized entries represent interpolations between calculated figures. Spot checks indicate that, generally, the impairments to the rotating Yagi's pattern caused by the fixed stack are less when the rotating Yagi's beam is perpendicular to that of the stack.

		largest change in spot gain to stack's pattern				largest change in spot gain to rotatable Yagi's pattern				
rotat'g Yagi az:		126°	216°	306°	36°	126°	216°	306°	36°	worst
λ	direction	right	opposite	left	parallel	right	opposite	left	parallel	change
0.00	180°	14.03	n/a	14.03	n/a	n/a	n/a	n/a	n/a	14.03
0.50	180°	5.22	4.95	5.22	21.65	n/a	10.43	n/a	19.78	21.65
0.75	180°	1.03	*4.49*	1.03	*19.68*	n/a	*8.74*	n/a	*11.16*	19.68
1.00	180°	0.97	4.03	0.97	17.70	n/a	7.05	n/a	2.54	17.70
1.50	180°	0.94	*3.47*	0.94	*15.73*	n/a	*6.02*	n/a	*2.16*	15.73
2.00	180°	0.66	2.91	0.66	13.75	n/a	4.98	n/a	1.78	13.75
3.00	180°	*0.50*	*2.19*	*0.50*	*11.66*	n/a	*2.98*	n/a	*1.42*	11.66
0.50	150°	*9.89*	10.25	*9.91*	17.65	n/a	10.63	n/a	13.61	17.65
0.75	150°	*7.35*	2.06	*7.76*	*15.44*	n/a	*8.28*	n/a	*7.56*	15.44
1.00	150°	*4.81*	2.16	*5.60*	13.23	n/a	5.92	n/a	1.51	13.23
1.50	150°	*4.11*	1.97	*4.68*	*13.34*	n/a	*8.80*	n/a	*1.80*	13.34
2.00	150°	*3.41*	19.00	*3.77*	13.45	n/a	11.67	n/a	2.08	19.00
3.00	150°	*2.71*	*16.60*	*3.51*	*11.99*	n/a	*11.15*	n/a	*1.67*	16.60
4.00	150°	n/a	14.20	n/a	10.53	n/a	10.63	n/a	1.25	14.20
0.50	135°	8.72	*18.06*	8.74	*14.94*	n/a	*13.54*	n/a	*12.58*	18.06
1.00	135°	3.85	*10.29*	4.44	*8.91*	n/a	*8.99*	n/a	*2.91*	10.29
2.00	135°	2.72	*9.59*	2.99	*6.82*	n/a	*5.77*	n/a	*2.29*	9.59
3.00	135°	*2.16*	*7.62*	2.76	*5.64*	n/a	*4.92*	n/a	*1.79*	7.62
0.50	120°	*9.63*	21.97	*10.29*	13.59	n/a	14.99	n/a	12.07	21.97
1.00	120°	*3.85*	14.35	*4.66*	6.75	n/a	10.53	n/a	3.61	14.35
2.00	120°	*2.27*	4.89	*2.63*	3.50	n/a	2.82	n/a	2.39	4.89
3.00	120°	*1.71*	*3.13*	*2.01*	*2.46*	n/a	*1.81*	n/a	*1.85*	3.13
0.50	90°	11.46	17.69	13.39	10.57	n/a	10.75	n/a	13.77	17.69
0.75	90°	5.96	*11.10*	9.53	*6.81*	n/a	*7.54*	n/a	*9.49*	11.10
1.00	90°	3.85	4.51	5.11	3.04	n/a	4.32	n/a	5.21	5.11
1.50	90°	*2.61*	1.92	*3.51*	*2.12*	n/a	1.53	n/a	2.27	3.51
2.00	90°	1.36	1.50	1.90	1.19	n/a	0.85	n/a	1.40	1.90
2.50	90°	*1.08*	0.49	*1.20*	0.68	n/a	0.52	n/a	1.11	1.20
3.00	90°	0.80	n/a	*0.50*	*0.50*	n/a	n/a	n/a	0.42	0.80

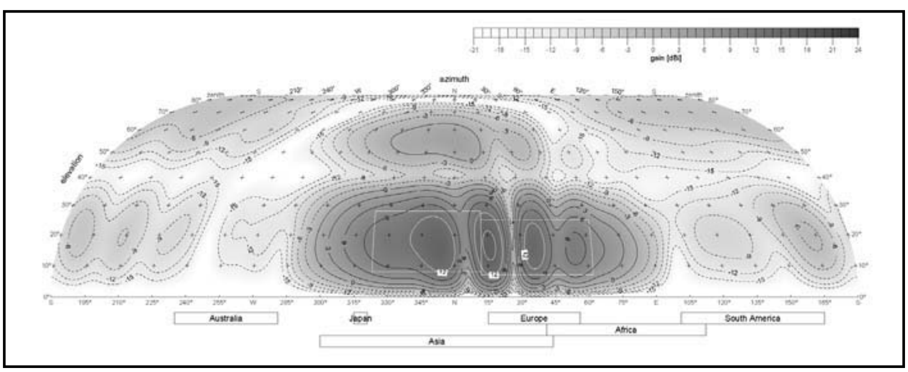


Figure 7—Pattern when driving the fixed 2-Yagi stack on Europe and the rotating single Yagi pointed at 351° azimuth. The beams of these two antenna systems overlap, creating destructive interference at key locations in the target zone.

beams as shown in Figure 6, but probably is not worth the extra effort to include the phase shifter.

Fixed Stack And Rotating Yagi

Problem: The same station in Austin, Texas uses a rotating Yagi to work all directions except for Europe; the fixed stack covers Europe. The two antenna systems must stand within 200 feet (3λ). Where should the rotating Yagi stand to minimize impairments?

We begin by assuming the operator never needs to point the rotating Yagi toward Europe, as the stack has superior performance in that direction. Let's examine the charts and tables of Parts 5 and 7 for hints as to good locations when the rotating Yagi points to the side or in the opposite direction as the stack.

Table 3 extracts data calculated in Parts 5 and 7 for all available positions (within 3 λ) of the rotating Yagi from off the side of the stack's boresight around to behind the stack. Beginning from the left, the first column is the distance between the antenna systems.

The second column is the relative direction from the stack's boresight to the rotating Yagi; i.e., 90° means the Yagi stands to the right of the stack (south and east) and 180° means the Yagi stands directly behind the stack (south and west).

The next three columns show the largest absolute change in any single spot of the pattern of the stack when the Yagi points to the four azimuths listed at the top of the column. These four azimuths represent directions at right angles, opposite, and parallel to the stack's main beam. A similar set of columns shows the largest absolute spot change to the Yagi's pattern due to the stack.

The rightmost column simply highlights the worst value across the row. For the four azimuths tested, the least impairments occur when the rotating Yagi is off to the side of the stack's main beam—even for separations down to less than 2 λ.

The listed azimuths, however, do not cover the entire range over which the operator needs the rotating Yagi. Let's do one more spot check by placing the rotating Yagi 3λ to the south and east of the European stack, and check impairments when the rotating Yagi points just 45° off the European stack's boresight, at 81° and 351° (the later somewhat overlooking the stack). A few model runs later, the stack emerges relatively unscathed, with no spot in its pattern deviating more than 1.8dB. The rotating Yagi's pattern also holds up, degrading no more than 1.5dB at any single spot. All of these pattern degradations are outside the main beams of these antennas, affecting only minor lobes and have no operational significance. Even at 2λ spacing with 351° azimuth, the worst impairment is a +4.6dB spot increase on a minor sidelobe.

Driving Both Systems Together

Earlier I showed a fixed stack and a separate fixed Yagi could be driven together to yield two beams of equal power to two targets, as long as due attention was paid to the driving currents.

Can one drive the fixed stack together with a rotating Yagi? Figure 7 shows the pattern when the rotating Yagi of our example Austin station points to 351°, and equal currents drive the two systems. The result is horrible: an enormous –20 dB hole right in the middle of the European beam!

Unfortunately, once the main beams of two antenna systems *in different locations* begin to overlap, a zone of destructive interference (cancellation) occurs between them. Adjusting the phase between the systems shifts the location of, but does not remove, this cancellation.

For typical Yagi systems employed by contesters, one may successfully drive two systems on different towers only if the main beams point in directions separated by at least 90°.

Conclusions

By applying the tools developed over this series, we have shown that one can successfully place a rotating Yagi surprisingly close to another fixed system, with insignificant interaction between the antennas when each is driven independently—as long as one chooses the correct locations!

As shown here as well as in earlier parts to this series, an unfortunate choice of locations can cause very serious impairments, including large holes in the main beam, a main beam pointing in the wrong direction, and large minor lobes that increase received QRM/QRN.

For the situation of a fixed stack and a rotatable Yagi on a second tower, we analyzed a short 2-Yagi stack at ½ and 1λ height, and a single rotating Yagi at ¾ λ, all using the 6-element OWA design:

Minimal interaction occurs when the rotating Yagi stands at right angles to the stack's main beam.

Interactions were minimal (<2dB) for separations of at least 2 λ, regardless of the direction of the rotating Yagi. Interactions essentially disappeared at 3 separation.

When the rotating Yagi points at least 90° off from the stack, one may feed both antenna systems simultaneously without destructive interference between the beams.

To equalize the gain in both beams, choose a proper ratio of drive currents. For the example analyzed, the best ratio was about 1.5 or 1.6 (single Yagi) to 1 (top of stack) to 1 (bottom of stack).

Next time we will look at interactions between 40 and 15meter Yagi systems.

Notes

[1]Scace, Eric K3NA; "Antenna Interactions—Part 1: Stop Squinting! Get the Big Picture", *National Contest Journal*, 2003 Jul/Aug; ARRL, Newington CT USA.

[2]Scace, Eric K3NA; "Antenna Interactions—Part 2: Twisting Stacks", *National Contest Journal*, 2003 Sep/Oct; ARRL, Newington CT USA.

[3]Scace, Eric K3NA; "Antenna Interactions—Part 3: When Good Aluminum Goes Bad", *National Contest Journal*, 2003 Nov/Dec; ARRL, Newington CT USA.

[4]Scace, Eric K3NA; "Antenna Interactions—Part 4: Cleaning Up Stacked Yagis with Current Tapers", *National Contest Journal,* 2004 Jan/Feb; ARRL, Newington CT USA.

[5]Scace, Eric K3NA; "Antenna Interactions—Part 5: How Close is Too Close?" *National Contest Journal,* 2004 Mar/Apr; ARRL, Newington CT USA.

[6]Scace, Eric K3NA; "Antenna Interactions—Part 6: Antennas Pointing in the Same Direction", *National Contest Journal,* 2004 Jul/Aug; ARRL, Newington CT USA. NCJ