Antenna Interactions – Part 4
Cleaning Up Stacked Yagis with Current Tapers

Eric L. Scace K3NA
eric@k3na.org

Reviewing progress to date:

- Part 1 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. Examples of siting problems in the design of a contesting station antenna farm were given but siting issues were not fully explored.[3]

Logically the next step is to explore the limits of siting antenna systems on the same band in order to develop some simple rules about where to locate and point antennas. In order to do that, we need to choose some design criteria for impairment.

For these articles, three criteria identify impairments:

- A decrease in median gain towards the target sector by more than a specified threshold. Locating another antenna so that a stack's signal strength towards its target declines certainly seems undesirable.
- A decline in the minimum gain within the target sector by more than a specified threshold. Even if the median gain towards the target is maintained, introducing holes in the pattern would also be undesirable.
- Introduction of sidelobes in non-targeted directions that exceed a threshold. The creation of sidelobes typically robs gain from the target and increases the exposure to QRN and QRM from non-targeted directions.

Before plowing forward to model impairments, we should start with a clean antenna pattern. Stacked Yagi systems used by most contesters actually do not deliver their full potential performance. Almost all of these systems feed approximately equal currents, either in phase or (occasionally) 180° out of phase, to each antenna. However, by using *different* currents – a process often referred to as "current tapering" by antenna engineers – significant reductions in unwanted sidelobes occur. This article introduces current tapering as a Yagi stack design technique.

1 General linear phased array design

Mathematical methods to design linear arrays of identical antennas have been available for some time.[4] The simplest linear phased arrays use identical spacing, with ½λ spacing producing the cleanest patterns and sharpest main lobes. Linear phased array pattern synthesis may also use:

- Non-uniform element currents to reduce sidelobes;
- Staggered phasing to steer the main beam off the direction that is orthogonal to the line of the array, with some tradeoffs such as increased sidelobes;
- Depopulation techniques, larger spacing, or non-uniform spacing to reduce the number of elements in a *very* large array containing many elements, typically trading off some combination of decreased pattern gain, increased main lobe width, increased sidelobes, or decreased frequency coverage.

One may consider a stacked Yagi system as a very small linear phased array, where each "element" is one Yagi, and with the array turned vertically and placed adjacent to an imperfect reflecting surface (the ground). The following characteristics of a stacked Yagi array have implications for applying traditional linear array pattern synthesis methods:

- We may exploit non-uniform driving currents to reduce sidelobes. Examples follow.
- We cannot apply staggered phasing techniques very effectively to stacked Yagis. The presence of the imperfect reflecting surface eliminates the ability to steer beams through staggered phasing, except for the degenerate case of 180° phase shifts. Staggered phasing smears out the main beam vertically, reducing gain and increasing sidelobes.
- We may increase vertical spacing beyond ½λ, such as the ¾λ spacing commonly used in contesters' stacks, but recognizing that this deteriorates the pattern through increased sidelobes.

---

[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 Aug/Sep; ARRL, Newington CT USA.

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

[4] See, for example, Hansen, R. C.; *Phased Array Antennas*; John Wiley & Sons; 1998; chapters 2 through 4.

- Contest station Yagi arrays do not have enough antennas to use depopulation techniques.
- The use of parasitic Yagi antennas as the “element” in a linear phased array somewhat limits the ability to remove all sidelobes and achieve maximum gain into the target zone. The currents in the parasitic directors and reflectors can not be as easily constrained as an array containing only driven elements. Some thoughts on how to work around this issue appear near the end of this article.

Lastly, the parasitic nature of Yagis and the imperfect reflection from ground render the mathematical pattern synthesis tools unusable. We must optimize stack performance through modeling and semi-automatic tweaking methods.

2 Current tapering a two-Yagi stack

Figure 1[5] shows a typical contesting stack of two Yagis mounted 1½λ and ¾λ above ground and fed in phase with equal currents. To allow comparison with results in other parts of this series, the models here all continue to use the 20m 6-element 48-ft boom OWA Yagis in use at K4JA, with “good ground” characteristics (5 mS/m, σ=13). The stack, at a location near Washington DC, points towards Europe. The target zone covers azimuths and elevation angles typically used to reach Europe on 20m throughout the solar cycle.

Now tweak the drive current of the top Yagi. Currents will be specified relative to the bottom Yagi; i.e., the bottom Yagi always has a relative current of 1.00 at a phase angle of 0°. A reduction of top Yagi drive current to about 0.81 yields the pattern in Figure 2. Figure 3 shows the difference between the two patterns.

The sidelobe just above the main beam has been reduced by –9 dB. The median gain in the target zone has increased trivially +0.1 dB. More importantly, the weakest signals in the target zone improve by +2.8 dB. The two large sidelobes, towards the rear and towards the zenith, remain unaffected.

The zenith lobe occurs because of the heights of the Yagis. Energy radiated straight down from the bottom Yagi at ¾λ reflects off the ground and undergoes a phase reversal, returning back up to the antenna’ and having covered a distance of 1½λ. Because of the phase reversal, it is now in phase with energy radiating up from the Yagi. To eliminate the zenith lobe requires mounting the Yagis at a multiple of ½λ above the ground.

Reposition the Yagis at 1λ and ½λ heights and start without current tapering. Figure 4 reveals the zenith lobe, as expected, has disappeared. The rear lobe is also dramatically reduced, in many areas by more than –15 dB and a welcome relief from QRN and QRM! Table 1 lists comparative pattern statistics. Even though the stack’s main lobe extends into elevation angles above the target sector, the median gain to the target is about the same a current-tapered stack at the higher heights of Figure 2. The weakest gain in the target sector has shifted to the bottom of the target. The reduced sidelobes cause a lower median gain outside the target.

Current tapering this low stack will reduce the sidelobes even further. However, as the drive current to the top antenna declines, the main lobe continues to expand upward in elevation and its peak gain starts to drop ever so slightly. Table 1 shows the incremental decline in median gain into the target zone as top antenna current drops by 10% increments to 0.90, 0.81 and finally 0.73. Figure 7 illustrates this last case, showing the lobes above 45° elevation have been reduced by -15 dB or more. Only two small spots in the upper half of the sky see a signal of –15 dBi (more than –30 dB below the main beam). For this system the amount of current taper is not very critical. All these current-tapered low two-Yagi stacks, although not quite perfectly aimed into the target sector, have very clean patterns.

Since the main lobe of this low stack has an elevation angle a bit higher than desired, one wonders if raising the stack to the next multiple of ½λ would bring the main lobe back down into the target zone. Figure 8 will not surprise experienced stack Yagi system designers. The main lobe of this equal-currents stack has split in the middle. The sidelobes are well down: no zenith lobe and the small minor rear lobes remain below –6 dBi. Nevertheless, the split main lobe remains a stubborn feature; even aggressive current tapering cannot make up for the cause of the split: the missing Yagi at ½λ. As current to the top antenna declines further the weak sidelobes populate the sky; Figure 9 and Table 1 show the gory details.

Conclusions about the two-Yagi stacks, pattern synthesis and current tapering:

- Yagi stacks must be mounted at multiples of ½λ in order to cancel the zenith sidelobe. These mounting heights also significantly reduce radiation in the rear quadrants.
- A low two-Yagi stack at 1λ and ½λ height illuminates the target sector the same as, and a dB or two in the corners better than, a two-Yagi stack at the more traditional 1½λ and ¾λ.
- This low two-Yagi stack, even without current tapering, has substantially reduced sidelobes compared to the traditional two-Yagi stack.
- Current tapering the low stack reduces high elevation angle sidelobes, moving that energy into the more useful lower elevation angles.
- Current tapering provides a superior two-Yagi stack on a tower one-third shorter than tradi-

[5] As usual, this article with all figures in color and all software meta-tools is available at www.ncjweb.com.

tional two-Yagi stack implementations commonly found today.

- As many earlier stack studies have shown[6], installing a two-Yagi stack too high causes the main beam to split. The upper half of the split main beam cannot be suppressed through current tapering.

3 Current tapering a three-Yagi stack

Building on the low two-Yagi stack, consider a short three-Yagi stack mounted at 1½λ, 1λ and ½λ above ground. Figure 10 shows this system fed with equal currents. No zenith sidelobe exists and the rear half of the sky hemisphere contains quite minor lobes with the worst at about –6 dBi. Above the main beam is a secondary beam centered on 51° elevation. Can current tapering reduce these extraneous lobes?

Table 2 shows pattern statistics for fifteen current-tapered three-Yagi stacks. All of these designs are excellent systems, with perhaps the 0.53 (top) 1.10 (middle) combination in Figure 14 the quietest of the group. The table and figures demonstrate that the tapered current values are not highly critical. Very good results occur with currents within ±10% on the middle Yagi. If one were to err, an error on the low side would be slightly preferable. The top Yagi's current can vary between –10% and +20% of 0.53 without difficulty.

The current-tapered three-Yagi stack fits on the same tower as the non-tapered, two-Yagi stack at 1½λ and ¾λ with which we started. Figure 16 highlights the changes:

- The median gain into the whole of the target sector is about the same, just +0.1 dB higher in the short three-Yagi stack, which is not operationally significant.
- The target zone receives a more uniform signal. In particular, gain at elevations from 15-24° has increased +1 to +8.8 dB.
- The main beam narrows. At the edges of the main beam, about ±60° in azimuth from the boresight and well outside the target sector, gain has been trimmed by as much as –10 dB.
- The rear lobes decline significantly: as much as –15 dB. The worst lobe in the rear quadrant is about –6 dBi, about –18 dB below the peak gain.
- All radiation above 30° disappears. 61% of the total sky has gain at or below –15 dBi. Gain at elevations above 37° is below –21 dBi (except for an area above the main beam, which is below –15 dBi).

This short stack is a much quieter receiving antenna. The reduction QRN and QRM from directions outside the target zone makes it easier to hear stations from the target.

Figure 17 shows the pattern of a more typical, taller three-Yagi stack at 2¼λ, 1½λ and ¾λ height. The taller stack concentrates more energy at the lower elevation angles typically used for band openings, so Table 3 shows pattern statistics for a target sector with elevation ranging between 1 and 17°. The first line of the table shows the short, current-tapered stack. The next line is the tall stack with equal currents. Not surprisingly, the tall stack is a little louder into the lower-angle target zone (+0.6 dB increase in median gain) and covers the very low 1° elevation angle more effectively.

Figure 18 is the same tall three-Yagi stack with current tapering. An exploration of various current tapers showed that only the top antenna needs adjustment to yield the cleanest pattern available for these mounting heights. Target sector coverage is improved somewhat and high angle sidelobes (except for the zenith) fade as much as –15 dB. However, the weak zenith lobe of –6 dBi persists, as does the extensive rear lobe at +3 dBi. The short stack's rear lobe is –15 to –18 dB lower than the tall stack.

To see how far performance could improve, I tapered currents on a four-Yagi stack mounted at 2λ (top), 1½λ (high), 1λ (middle) and ½λ (bottom). Table 4 and Figure 20 to Figure 24 summarize the results. Despite the slightly shorter height, the best of the current-tapered four-Yagi stacks show advantages compared to the current-tapered tall three-Yagi stack:

- +0.6 dB increased median gain across the entire target zone.
- +0.5 dB higher peak gain, with the main beam centered in the target.
- rear quadrant lobes all reduced to below –5 dBi, an improvement of up to –19 dB.
- Gains below –15 dBi across two-thirds of the sky hemisphere.
- Current taper tolerances are pretty relaxed. Variations of ±10% or even more do not introduce significant variations in these patterns.

Depending on the current taper chosen, some unavoidable minor grating lobes appear above the main beam and above the target zone. I would probably choose the symmetrical current taper of about 1.0 (top), 1.8, 1.8 and 1.0 (bottom) as a slight favorite. Its grating lobes are at 0 dBi (-18 dB below the main beam peak) and –15 dBi (-33 dB below peak gain). The worst rear lobes are –5 dBi (–23 dB below peak gain) and the entire rear quadrant above 20° elevation is less than –15 dBi, a very quiet antenna.

Although I have not modeled this yet, I suspect that replacing the 6-element OWA Yagis in this stack with 5-element or even 4-element Yagis would continue to provide excellent results.

[6] Donavan, Frank W3LPL and Brosnahan, John W0UN; *Unofficial Proceedings of … 1992 [Dayton] Antenna Forum;* LTA, New Bedford PA; 1992; pp 1-53.

4 Optimizing current taper

Since each band and station location has a different description of target zones (e.g., elevation angles can be different), it's worth explaining how I chose these current tapers. I changed current levels in steps of ±10% times the previous level; i.e., in the sequence 0.28, 0.31, 0.35, … 0.81, 0.90, 1.00, 1.10, 1.21, … 1.95 and 2.14. When initially searching for clean patterns jumps of ±20% worked fine.

Optimizing the current taper for a two-Yagi stack is straightforward; only one parameter (top Yagi current) can be tweaked. Striving for the largest percentage of sky below –15 dBi seems to work fine in zeroing in on a clean pattern with good target zone performance. The cleanest patterns did not coincide with the patterns with largest median gain to the target sector, but were within a fraction of a dB.

Three-Yagi stacks have two current parameters to tweak. Tweaking for maximum sky below –15 dBi worked well again as initial guidance. To work systematically and keep track of comparative results, I used an optimizing table; an example is in Table 5. The table is a two-dimensional matrix with top antenna current varying across the columns and current for the next lower antenna varying down the rows. As each pattern was calculated, I entered the percentage of sky below –15 dBi at the intersection of the proper row and column. The best two or three patterns in each row, column, and diagonal (from upper left to lower right) were compared to their neighbors. In comparing, I weighted median gain and percentage of sky below –15 dBi about equally. For very similar cases, I also considered the worst gain within the target zone and overall pattern cleanliness (minimizing minor lobes).

In practice, the fastest convergence on good results occurred when moving within the matrix from an initial guess diagonally along the upper left-lower right direction to find a local best case, and then checked horizontally (and then vertically) for improvements. After comparing each pair of neighboring patterns, I marked an arrow pointed to the preferred pattern. When a group of arrows all pointed to the same pattern, optimization was done. With an educated guess for a starting point, about ten patterns were sufficient to finalize the optimization. It took two to three minutes to prepare the NEC input, run NEC4 and process the results with the meta-tools for each pattern.

For the four-Yagi stack optimization, I picked a value for the second antenna from the bottom. The two-dimensional optimization matrix then governed the tweaking of currents for the top and second from top antennas. The best result was saved for a final beauty pageant. I built five such matrices, for five different currents in the next-to-lowest Yagi. Table 4 and Figure 20 through Figure 24 describe the best patterns from each matrix. Although this procedure was occasionally tedious, the coding and testing of an automatic optimizer would have taken much longer.

5 Further investigations

We've just cracked the door open on applying meta-tools and current tapering to stacks; there are many further areas to explore. For example, at this point I do not know if the same current tapers remain optimum when the type of Yagi inside the stack is changed.

This article has not covered feed systems for current tapering. The techniques for designing suitable current feed systems are identical to those applied to phased vertical arrays.[7] I encourage others experienced in the art to contribute solutions that tolerate typical feedpoint drive impedance variations across the band.

Stacked Yagi arrays might improve further by re-optimizing the design of the Yagi used inside the array. Many past optimization efforts tweak the design of a single Yagi in isolation. The outputs of the meta-tools developed for this series of articles can drive the tweaking of Yagi design for improved uniform performance of the complete stack across the band. (A later part will introduce another meta-tool that evaluates sky hemisphere and target zone pattern statistics for multiple frequencies across a band. Such tools are an important precaution to avoid spot frequency super-designs whose performance collapses a few kHz away.)

Having characterized some very clean arrays, in the next part of this series we will return to siting issues.

6 Updates

Unfortunately I gave the publisher the wrong monochrome map for the bottom half of Part 3 Figure 1, prompting a batch of emails from puzzled readers. The correct map is printed here and available (in color) on the *NCJ* website www.ncjweb.com. Also available is an updated AEGBin.awk meta-tool file that corrects a minor labeling error in the pattern statistics shown on the website's color maps. An updated NOUTrim.awk meta-tool includes the calculation of percent sky with gain below the gain floor.

[7] Devoldere, John ON4UN; *Low-Band DXing 3rd edition;* ARRL, Newington CT USA; 1999 contains a good summary of these techniques and extensive references to more detailed explanations. The 4th edition is in preparation.

height λ top	height λ bot	current top	target sector gain median	target sector gain max	target sector gain min @ el	non-target median	Figure
1½	¾	1.00	+13.44	+16.74	+0.18 @ 23°	-10.27	Figure 1
		0.81	+13.53	+16.59	+2.77 @ 23°	-10.91	Figure 2
1—	½	1.00	+13.57	+15.76	+1.84 @ 2°	-14.94	Figure 4
		0.90	+13.51	+15.67	+1.63 @ 2°	below -15	Figure 5
		0.81	+13.44	+15.55	+1.38 @ 2°	below -15	Figure 6
		0.73	+13.34	+15.41	+1.12 @ 2°	below -15	Figure 7
1½	1—	1.00	+13.24	+16.99	-6.38 @ 23°	below –15	Figure 8
		0.90	+13.33	+16.95	-6.92 @ 23°	below –15	—
		0.81	+13.35	+16.89	-5.73 @ 23°	-14.97	—
		0.66	+13.37	+16.70	-2.03 @ 23°	-13.73	Figure 9
		0.53	+13.29	+16.47	+1.03 @ 23°	-12.66	—

Table 1 — Comparison of equal-current and current-tapered two-Yagi stacks at various heights. Gains and currents presented to hundredths to show trends. Current is relative to bottom antenna. Gain in dBi.

height λ top	height λ mid	height λ bot	current top	current mid	target sector gain median	target sector gain max	target sector gain min @ el	non-target median	Figure
1½		¾	1.00		+13.44	+16.74	+0.18 @ 23°	-10.27	Figure 1
1—		½	0.90		+13.51	+15.67	+1.63 @ 2°	below -15	Figure 5
1½	1—	½	1.00	1.00	+14.05	+17.20	+3.93 @ 23°	-14.15	Figure 10
			0.73	1.10	+14.07	+16.97	+5.02 @ 2°	below –15	—
				1.21	+14.08	+16.96	+4.94 @ 2°	below –15	Figure 11
				1.33	+14.08	+16.93	+4.85 @ 2°	below –15	—
			0.66	1.10	+14.06	+16.88	+4.80 @ 2°	below –15	—
				1.21	+14.04	+16.87	+4.72 @ 2°	below –15	Figure 12
				1.33	+14.05	+16.84	+4.62 @ 2°	below –15	—
			0.59	1.00	+14.02	+16.78	+4.60 @ 2°	below –15	—
				1.10	+14.06	+16.78	+4.55 @ 2°	below –15	Figure 13
				1.21	+14.05	+16.77	+4.47 @ 2°	below –15	—
			0.53	1.00	+14.00	+16.68	+4.36 @ 2°	below –15	—
				1.10	+14.02	+16.68	+4.31 @ 2°	below –15	Figure 14
				1.21	+13.99	+16.67	+4.24 @ 2°	below –15	—
			0.47	0.90	+13.89	+16.53	+4.12 @ 2°	below –15	—
				1.00	+13.91	+16.56	+4.09 @ 2°	below –15	Figure 15
				1.10	+13.91	+16.57	+4.05 @ 2°	below –15	—

Table 2 — Comparison of equal-current and current-tapered three-Yagi stacks. Gains and currents presented to hundredths to show trends. Current is relative to bottom antenna. Gain in dBi. For comparison, the first line is a typical two-Yagi stack without current tapering. The second line is the best current-tapered low two-Yagi stack from Table 1. The last line is a typical three-Yagi stack without current tapering.

height λ top	height λ mid	height λ bot	current top	current mid	target sector gain median	target sector gain max	target sector gain min @ el	non-target median	Figure
1½	1—	½	0.53	1.10	+14.42	+16.68	+0.02 @ 1°	below –15	Figure 14
2¼	1½	¾	1.00	1.00	+14.82	+18.24	+3.41 @ 16°	-13.02	Figure 17
			0.43	1.00	+14.86	+17.58	+4.05 @ 1°	below -15	Figure 18

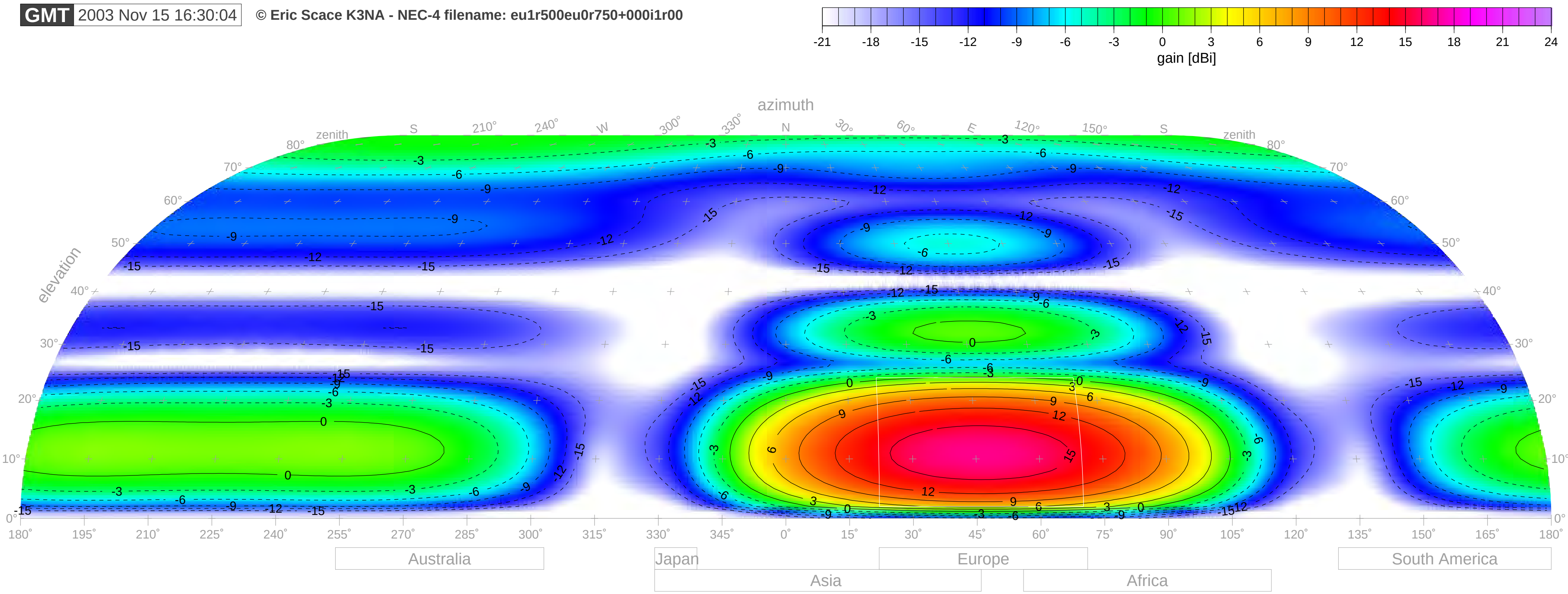
Table 3 — Comparison of short and tall three-Yagi stacks. Since one typically uses taller stacks typically during band openings and closings on 20m from the USA mid-Atlantic region, the target sector has been shortened to 1-17° elevation.

height λ				current			target sector gain			sky	
top	hi	mid	bot	top	high	mid	median	max @ el	min @ el	≤-15dBi	Figure
2¼		1½	¾	0.43		1.00	+14.86	+17.58 8°	+4.05 1°	53.5%	Figure 18
				0.43	1.00	1.33	+15.25	+17.68 10°	+2.63 1°	67.2%	Figure 20
				0.59	1.21	1.46	+15.35	+17.89 9°	+3.14 1°	67.1%	Figure 21
2—	1½	1—	½	0.81	1.46	1.61	+15.47	+18.11 9°	+3.61 1°	66.9%	Figure 22
				1.00	1.77	1.77	+15.47	+18.21 9°	+3.86 1°	66.4%	Figure 23
				1.10	1.95	1.95	+15.47	+18.22 9°	+3.89 1°	65.9%	Figure 24

Table 4 — Comparison of tall three-Yagi stack (first row, with current taper) and slightly shorter four-Yagi stacks with various current taper schemes. The target sector includes elevations of 1-17°. The median gain in the non-target area of the sky was below –15 dBi for each stack.

1.77 current in middle Yagi		relative current in top Yagi			
		0.90	1.00	1.10	1.21
relative current in high Yagi	1.61	66.2% ↘	63.5% ↓		
		↘	↓		
	1.77	65.8% →	→ 66.4% ←	← 65.6% ←	← 63.1%
			↑ ↖	↖	↖
	1.95		↑ 64.6%	65.2%	65.2%

Table 5 — Two-dimension optimizing matrix for the four-Yagi stack. Currents are relative to 1.00 for the bottom Yagi of the stack. For this matrix the “middle Yagi” (second from bottom) was set to a relative current of 1.77. Arrows show the preferred pattern for each comparison pairing. Matrix cell entry is percent of sky below –15 dBi. While this statistic was helpful in locating good patterns, the evaluation of pattern pairs also considered median, peak and minimum gain to the target sector and attempted to minimize any minor lobes without significant sacrifice in target sector gain.



Optimize heights and current taper.
2 antennas present:
 Eu20mid Yagi20648   Height: 1.500 wavelngth. 46° azimuth.   <-- Feedpoint # 1
 Eu20bot Yagi20648   Height: 0.750 wavelngth. 46° azimuth.   <-- Feedpoint # 2
Card deck created 03 Nov 15 Sat 16:29:30 -0500

NEC version 4.1

K3NA NOUTrim v3.7 2003 Jul 21 Mon

14.025 MHz

finite ground. sommerfeld solution
 13.0 dielectric constant
 5.0 mS/m

Drive impedance; voltage or current:
#1: 30.2 - j 6.0 Ω   1.000A ∠ -90.0°
#2: 31.1 - j 5.5 Ω   1.000A ∠ -90.0°

Maximum gain: +16.74 dBi at 46° az 10° el.
87.0 % power efficiency.

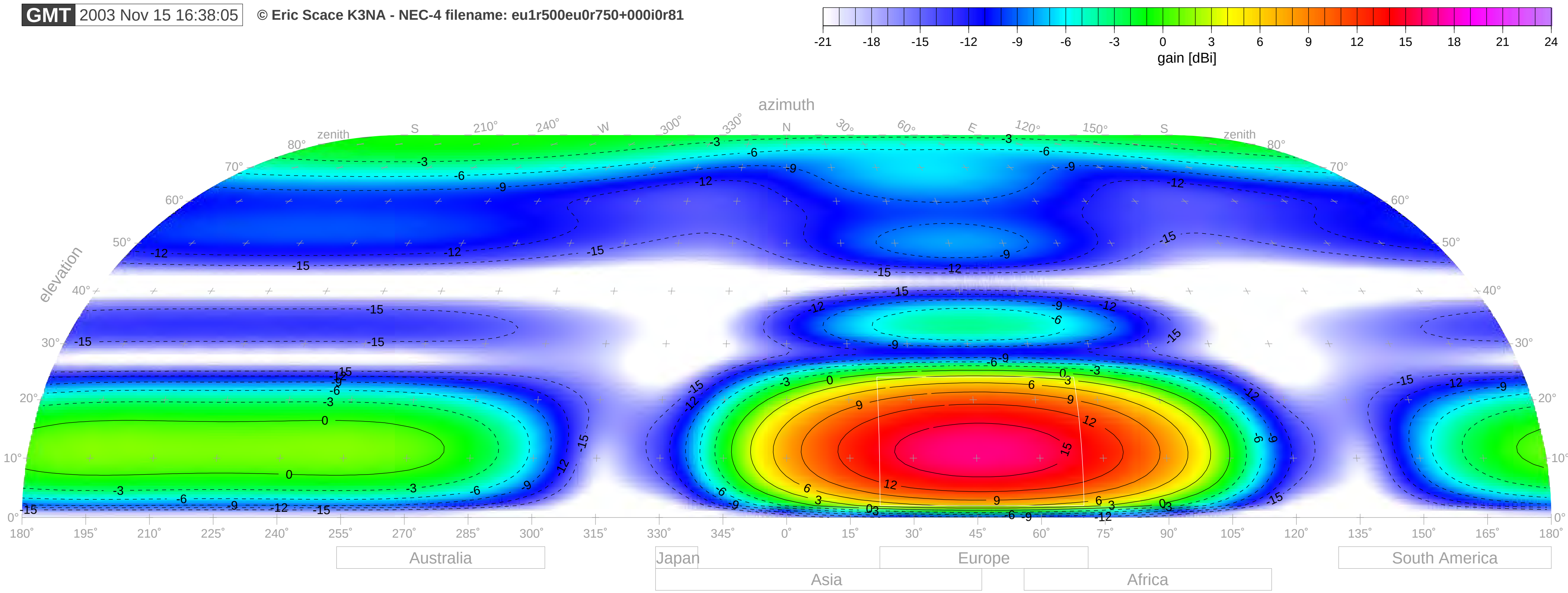
Target 1 - Europe_20m_from_W3: 22- 70° az 2-24° el.
 Median gain*: +13.44 dBi. Avg dev: +1.91 above, -3.37 below.
 Min: +0.18 dBi at 69° az 23° el.   Max: +16.74 dBi at 46° az 10° el.

Target 2 not used.

Non-targeted area statistics:
 Median gain*: -10.27 dBi. Avg dev: +11.44 above, -3.48 below.
 Min: -52.38 dBi at 320° az 40° el.   Max: +14.47 dBi at 70° az 10° el.

* Gain floor for calculating median, mean and deviation is -15.0 dBi.
NEC x-axis is North azimuth.

Figure 1 - Typical contesting stack of two Yagis mounted 1½λ and ¾λ above good ground, fed with equal currents in phase.



Optimize heights and current taper.
2 antennas present:
Eu20mid Yagi20648 Height: 1.500 wavelngth. 46° azimuth. <-- Feedpoint # 1
Eu20bot Yagi20648 Height: 0.750 wavelngth. 46° azimuth. <-- Feedpoint # 2
Card deck created 03 Nov 15 Sat 16:37:31 -0500

NEC version 4.1

K3NA NOUTrim v3.7 2003 Jul 21 Mon

14.025 MHz

finite ground. sommerfeld solution
13.0 dielectric constant
5.0 mS/m

Drive impedance; voltage or current:
#1: 30.6 - j 5.1 Ω 0.810A ∠ -90.0°
#2: 30.8 - j 6.2 Ω 1.000A ∠ -90.0°

Maximum gain: +16.59 dBi at 46° az 11° el.
86.4 % power efficiency.

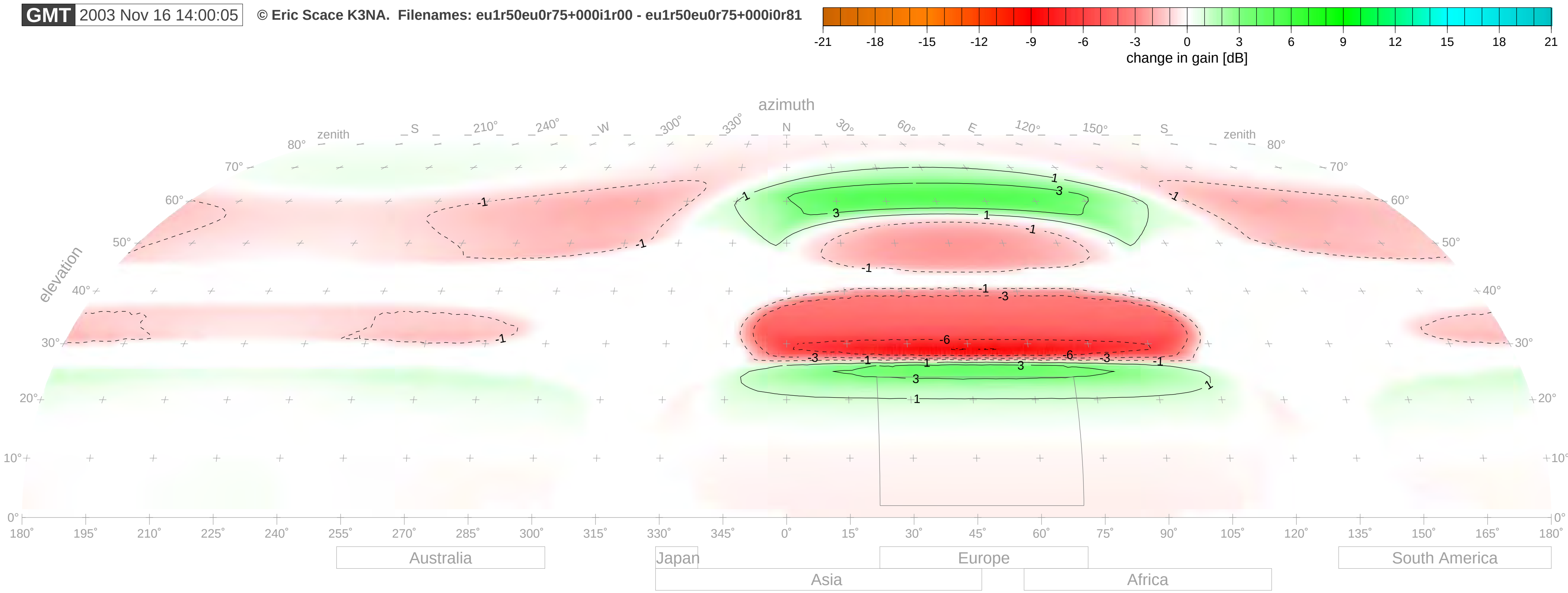
Target 1 - Europe_20m_from_W3: 22- 70° az 2-24° el.
Median gain*: +13.53 dBi. Avg dev: +1.72 above, -3.16 below.
Min: +2.77 dBi at 69° az 23° el. Max: +16.59 dBi at 46° az 11° el.

Target 2 not used.

Non-targeted area statistics:
Median gain*: -10.91 dBi. Avg dev: +11.99 above, -3.11 below.
Min: -45.79 dBi at 123° az 40° el. Max: +14.30 dBi at 70° az 10° el.

* Gain floor for calculating median, mean and deviation is -15.0 dBi.
NEC x-axis is North azimuth.

Figure 2 - Same stack as Figure 1 except top Yagi current reduced to 0.81.



Optimize heights and current taper.
2 antennas present:
Eu20mid Yagi20648 Height: 1.500 wavelngth. 46° azimuth. <-- Feec
Eu20bot Yagi20648 Height: 0.750 wavelngth. 46° azimuth. <-- Feed
Card deck created 03 Nov 15 Sat 16:29:30 -0500

NEC version 4.1

K3NA NOUTrim v3.7 2003 Jul 21 Mon

Optimize heights and current taper.
2 antennas present:
Eu20mid Yagi20648 Height: 1.500 wavelngth. 46° azimuth. <-- Feec
Eu20bot Yagi20648 Height: 0.750 wavelngth. 46° azimuth. <-- Feed
Card deck created 03 Nov 15 Sat 16:37:31 -0500

NEC version 4.1

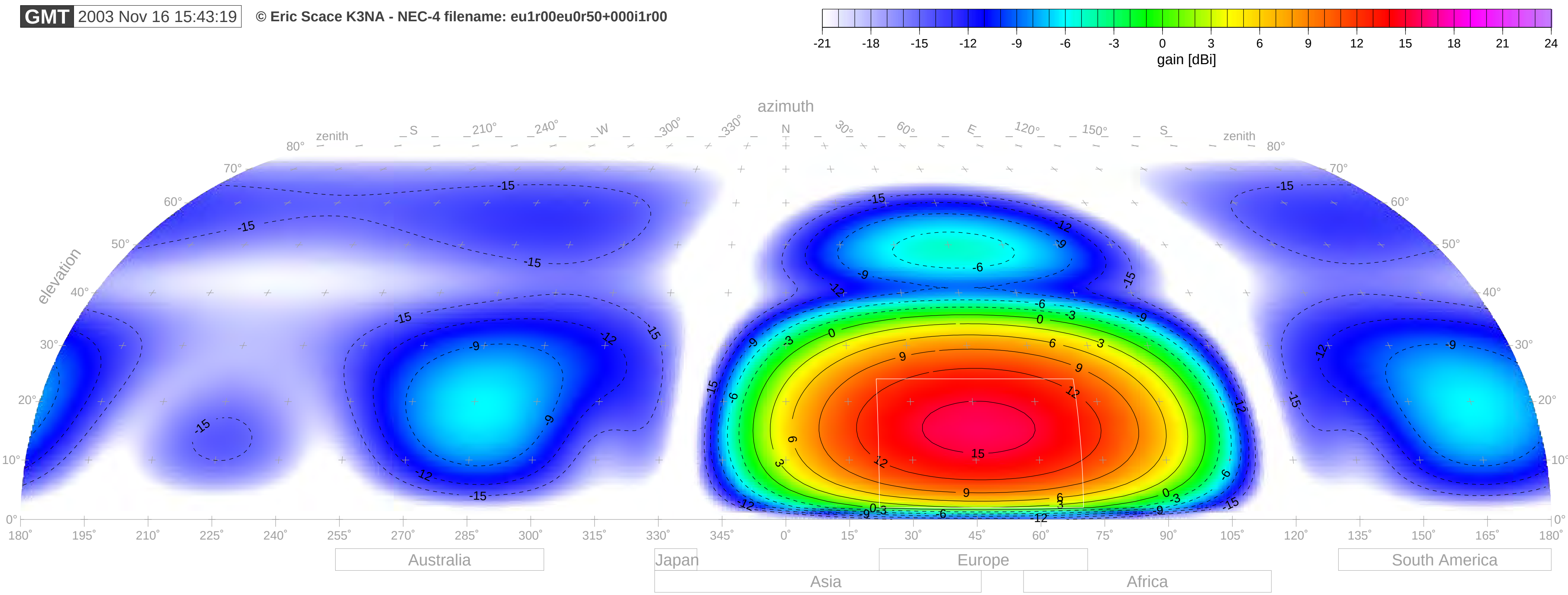
K3NA NOUTrim v3.7 2003 Jul 21 Mon

Target 1 - Europe_20m_from_W3: 22- 70° az 2-24° el.
Largest decrease: -0.35 dB at 70° az 2° el.
Largest increase: +2.77 dB at 50° az 23° el.
Median difference: -0.07 dB.

Non-targeted area statistics:
Largest decrease: -8.93 dB at 46° az 28° el.
Largest increase: +5.15 dB at 50° az 60° el.
Median difference: +0.00 dB.

* Gain floor for calculating differences is -15.0 dBi.
NEC x-axis is North azimuth.
Statistics computed by AEGBin v1.2 - 2003 Nov 15 Sat.

Figure 3 - Pattern changes caused by current tapering the two-Yagi stack of Figure 1 into that of Figure 2.



Optimize heights and current taper.
2 antennas present:
Eu20mid Yagi20648 Height: 1.000 wavelngth. 46° azimuth. <-- Feedpoint # 1
Eu20bot Yagi20648 Height: 0.500 wavelngth. 46° azimuth. <-- Feedpoint # 2
Card deck created 03 Nov 16 Sun 15:42:42 -0500

NEC version 4.1

K3NA NOUTrim v3.7 2003 Jul 21 Mon

14.025 MHz

finite ground. sommerfeld solution
13.0 dielectric constant
5.0 mS/m

Drive impedance; voltage or current:
#1: 27.5 - j 8.0 Ω 1.000A ∠ -90.0°
#2: 26.6 - j 7.6 Ω 1.000A ∠ -90.0°

Maximum gain: +15.76 dBi at 46° az 15° el.
85.7 % power efficiency.

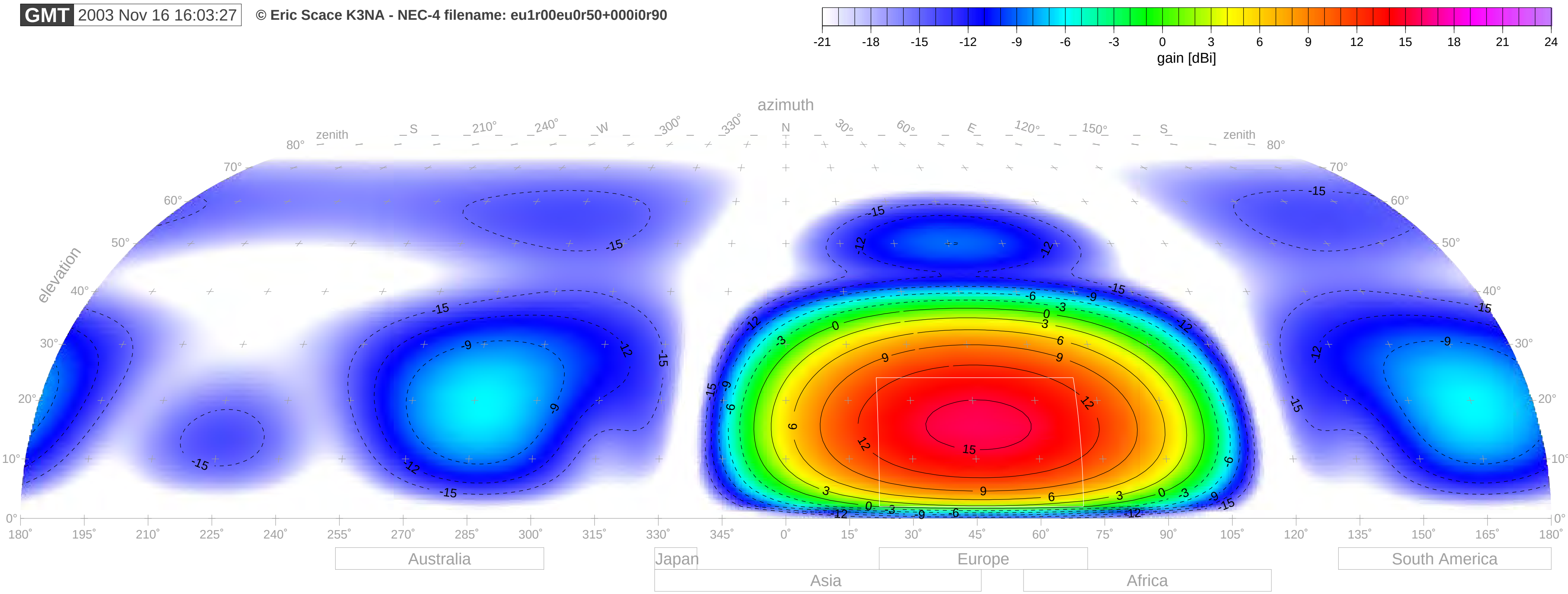
Target 1 - Europe_20m_from_W3: 22- 70° az 2-24° el.
Median gain*: +13.57 dBi. Avg dev: +1.16 above, -2.33 below.
Min: +1.84 dBi at 70° az 2° el. Max: +15.76 dBi at 46° az 15° el.

Target 2 not used.

Non-targeted area statistics:
Median gain*: -14.94 dBi. Avg dev: +16.21 above, -0.06 below.
Min: -55.52 dBi at 335° az 0° el. Max: +13.22 dBi at 21° az 15° el.

* Gain floor for calculating median, mean and deviation is -15.0 dBi.
NEC x-axis is North azimuth.

Figure 4 - Two-Yagi stack mounted at 1λ and ½λ with no current taper. Zenith lobe has disappeared and rear lobe dramatically reduced.



Optimize heights and current taper.
2 antennas present:
Eu20mid Yagi20648 Height: 1.000 wavelngth. 46° azimuth. <-- Feedpoint # 1
Eu20bot Yagi20648 Height: 0.500 wavelngth. 46° azimuth. <-- Feedpoint # 2
Card deck created 03 Nov 16 Sun 16:02:53 -0500

NEC version 4.1

K3NA NOUTrim v3.7 2003 Jul 21 Mon

14.025 MHz

finite ground. sommerfeld solution
13.0 dielectric constant
5.0 mS/m

Drive impedance; voltage or current:
#1: 27.3 - j 7.5 Ω 0.900A ∠ -90.0°
#2: 26.7 - j 8.1 Ω 1.000A ∠ -90.0°

Maximum gain: +15.67 dBi at 46° az 15° el.
85.3 % power efficiency.

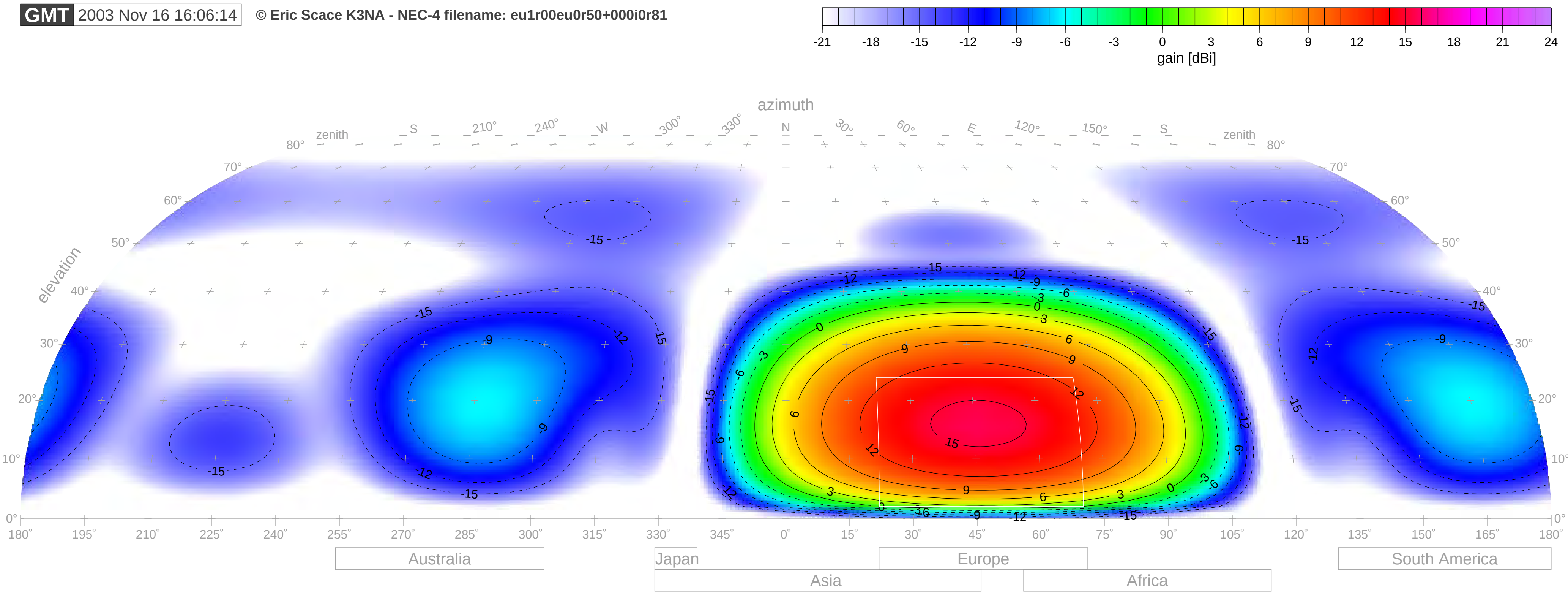
Target 1 - Europe_20m_from_W3: 22- 70° az 2-24° el.
Median gain*: +13.51 dBi. Avg dev: +1.14 above, -2.37 below.
Min: +1.63 dBi at 70° az 2° el. Max: +15.67 dBi at 46° az 15° el.

Target 2 not used.

Non-targeted area statistics:
Median gain*: -15.00 dBi. Avg dev: +16.75 above, +0.00 below.
Min: -56.85 dBi at 336° az 0° el. Max: +13.12 dBi at 21° az 15° el.

* Gain floor for calculating median, mean and deviation is -15.0 dBi.
NEC x-axis is North azimuth.

Figure 5 - Same stack as Figure 4 with top antenna current tapered to 0.90 for further reduction of signals above 45° elevation.



Optimize heights and current taper.
2 antennas present:
 Eu20mid Yagi20648   Height: 1.000 wavelngth. 46° azimuth.   <-- Feedpoint # 1
 Eu20bot Yagi20648   Height: 0.500 wavelngth. 46° azimuth.   <-- Feedpoint # 2
Card deck created 03 Nov 16 Sun 16:05:41 -0500

NEC version 4.1

K3NA NOUTrim v3.7 2003 Jul 21 Mon

14.025 MHz

finite ground. sommerfeld solution
   13.0 dielectric constant
   5.0 mS/m

Drive impedance; voltage or current:
#1: 27.2 - j 6.9 Ω   0.810A ∠ -90.0°
#2: 26.8 - j 8.5 Ω   1.000A ∠ -90.0°

Maximum gain: +15.55 dBi at 46° az 15° el.
84.8 % power efficiency.

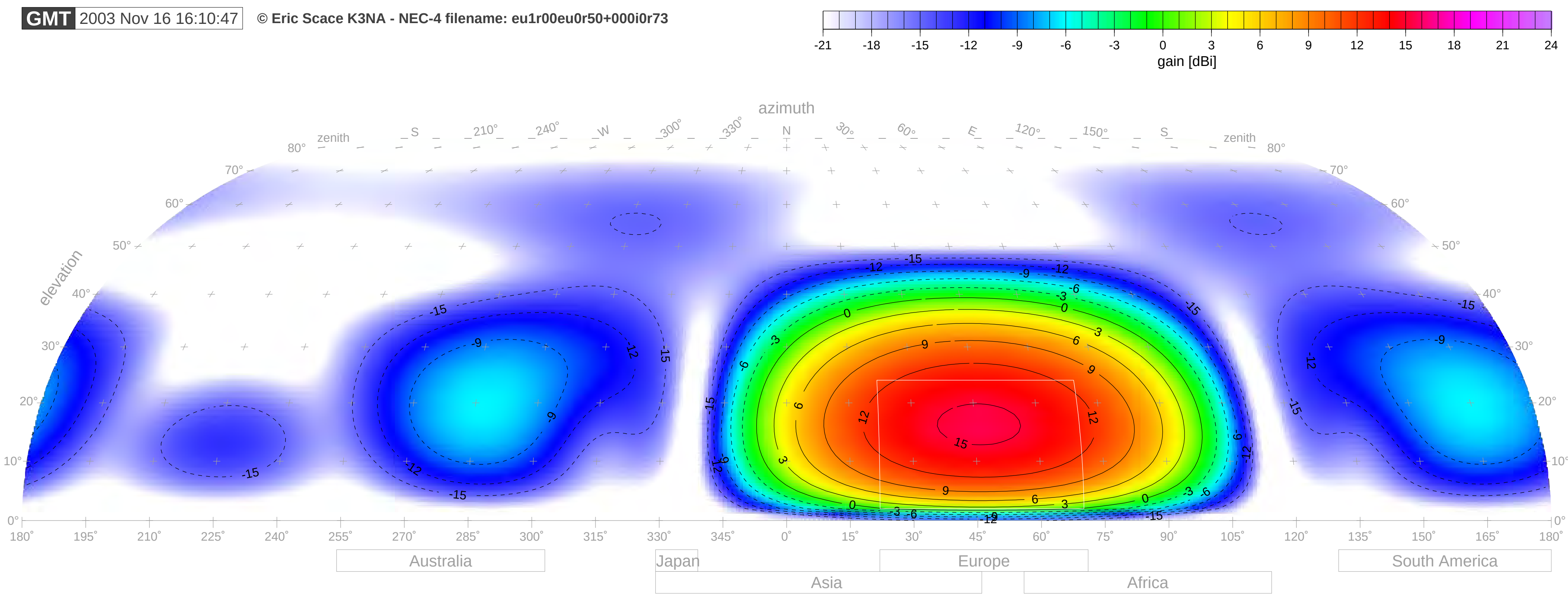
Target 1 - Europe_20m_from_W3: 22- 70° az 2-24° el.
   Median gain*: +13.44 dBi. Avg dev: +1.12 above, -2.43 below.
   Min: +1.38 dBi at 70° az 2° el.   Max: +15.55 dBi at 46° az 15° el.

Target 2 not used.

Non-targeted area statistics:
   Median gain*: -15.00 dBi. Avg dev: +17.26 above, +0.00 below.
   Min: -58.74 dBi at 336° az 0° el.   Max: +13.24 dBi at 46° az 24° el.

* Gain floor for calculating median, mean and deviation is -15.0 dBi.
NEC x-axis is North azimuth.

Figure 6 - Same stack as Figure 4 with top antenna current tapered to 0.81 for reduction of signals above 45° elevation.



Optimize heights and current taper.
2 antennas present:
Eu20mid Yagi20648 Height: 1.000 wavelngth. 46° azimuth. <-- Feedpoint # 1
Eu20bot Yagi20648 Height: 0.500 wavelngth. 46° azimuth. <-- Feedpoint # 2
Card deck created 03 Nov 16 Sun 16:10:13 -0500

NEC version 4.1

K3NA NOUTrim v3.7 2003 Jul 21 Mon

14.025 MHz

finite ground. sommerfeld solution
13.0 dielectric constant
5.0 mS/m

Drive impedance; voltage or current:
#1: 27.1 - j 6.3 Ω 0.730A ∠ -90.0°
#2: 26.9 - j 8.9 Ω 1.000A ∠ -90.0°

Maximum gain: +15.41 dBi at 46° az 16° el.
84.4 % power efficiency.

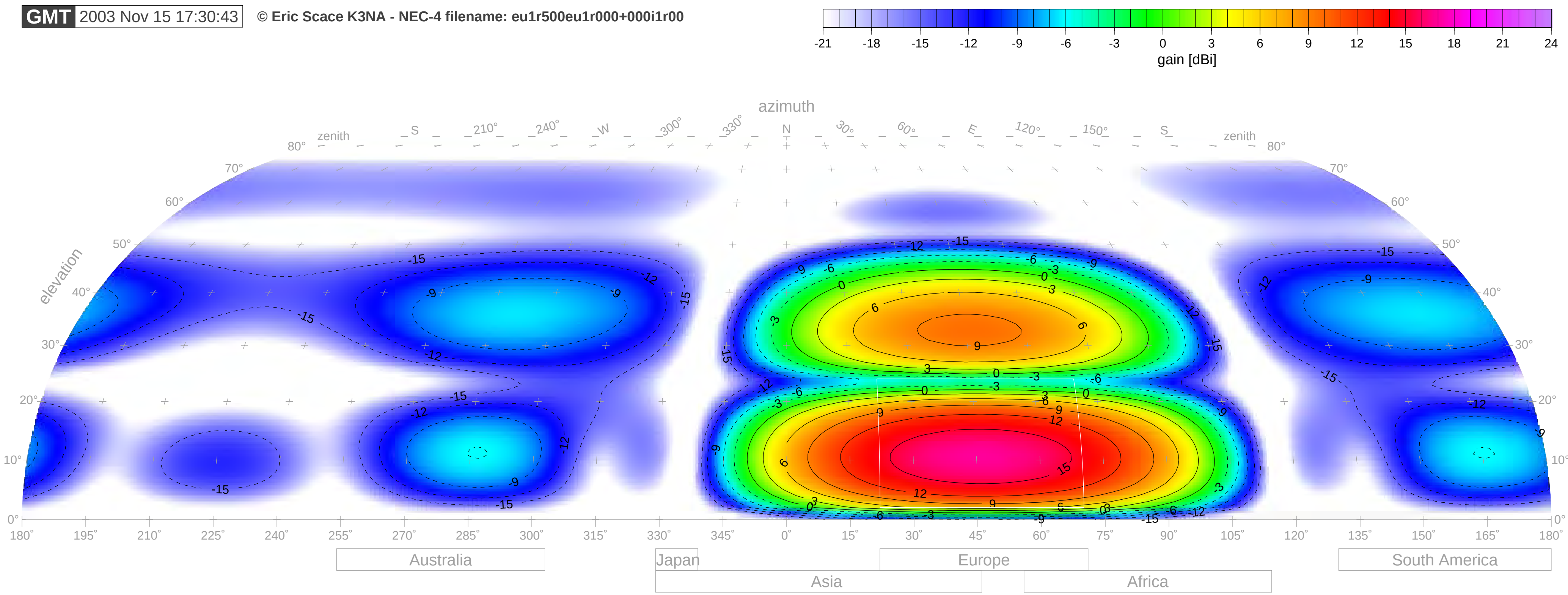
Target 1 - Europe_20m_from_W3: 22- 70° az 2-24° el.
Median gain*: +13.34 dBi. Avg dev: +1.10 above, -2.49 below.
Min: +1.12 dBi at 70° az 2° el. Max: +15.41 dBi at 46° az 16° el.

Target 2 not used.

Non-targeted area statistics:
Median gain*: -15.00 dBi. Avg dev: +17.30 above, +0.00 below.
Min: -59.49 dBi at 116° az 0° el. Max: +13.36 dBi at 46° az 24° el.

* Gain floor for calculating median, mean and deviation is -15.0 dBi.
NEC x-axis is North azimuth.

Figure 7 - Same stack as Figure 4 with current tapering used to suppress all radiation above 45° elevation to below -15 dBi.



Optimize heights and current taper.
2 antennas present:
Eu20mid Yagi20648 Height: 1.500 wavelngth. 46° azimuth. <-- Feedpoint # 1
Eu20bot Yagi20648 Height: 1.000 wavelngth. 46° azimuth. <-- Feedpoint # 2
Card deck created 03 Nov 15 Sat 17:30:09 -0500

NEC version 4.1

K3NA NOUTrim v3.7 2003 Jul 21 Mon

14.025 MHz

finite ground. sommerfeld solution
13.0 dielectric constant
5.0 mS/m

Drive impedance; voltage or current:
#1: 27.2 - j 8.0 Ω 1.000A ∠ -90.0°
#2: 27.1 - j 8.0 Ω 1.000A ∠ -90.0°

Maximum gain: +16.99 dBi at 46° az 10° el.
86.9 % power efficiency.

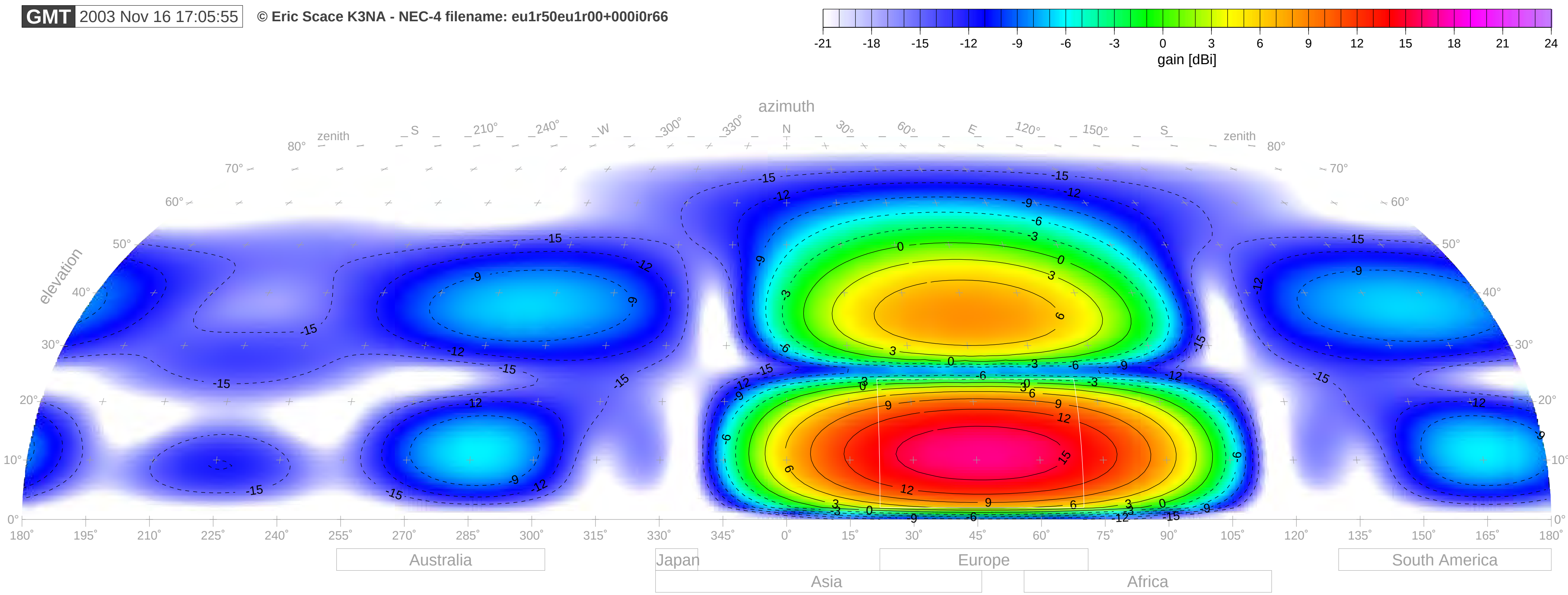
Target 1 - Europe_20m_from_W3: 22- 70° az 2-24° el.
Median gain*: +13.24 dBi. Avg dev: +2.19 above, -4.00 below.
Min: -6.38 dBi at 69° az 23° el. Max: +16.99 dBi at 46° az 10° el.

Target 2 not used.

Non-targeted area statistics:
Median gain*: -15.00 dBi. Avg dev: +16.57 above, +0.00 below.
Min: -53.98 dBi at 117° az 0° el. Max: +14.46 dBi at 70° az 10° el.

* Gain floor for calculating median, mean and deviation is -15.0 dBi.
NEC x-axis is North azimuth.

Figure 8 - Two-Yagi stack mounted at 1½λ and 1λ heights.



Optimize heights and current taper.
2 antennas present:
 Eu20mid Yagi20648   Height: 1.500 wavelngth. 46° azimuth.   <-- Feedpoint # 1
 Eu20bot Yagi20648   Height: 1.000 wavelngth. 46° azimuth.   <-- Feedpoint # 2
Card deck created 03 Nov 16 Sun 17:05:21 -0500

NEC version 4.1

K3NA NOUTrim v3.7 2003 Jul 21 Mon

14.025 MHz

finite ground. sommerfeld solution
   13.0 dielectric constant
   5.0 mS/m

Drive impedance; voltage or current:
#1: 26.5 - j 5.4 Ω   0.660A ∠ -90.0°
#2: 27.6 - j 9.7 Ω   1.000A ∠ -90.0°

Maximum gain: +16.70 dBi at 46° az 10° el.
85.2 % power efficiency.

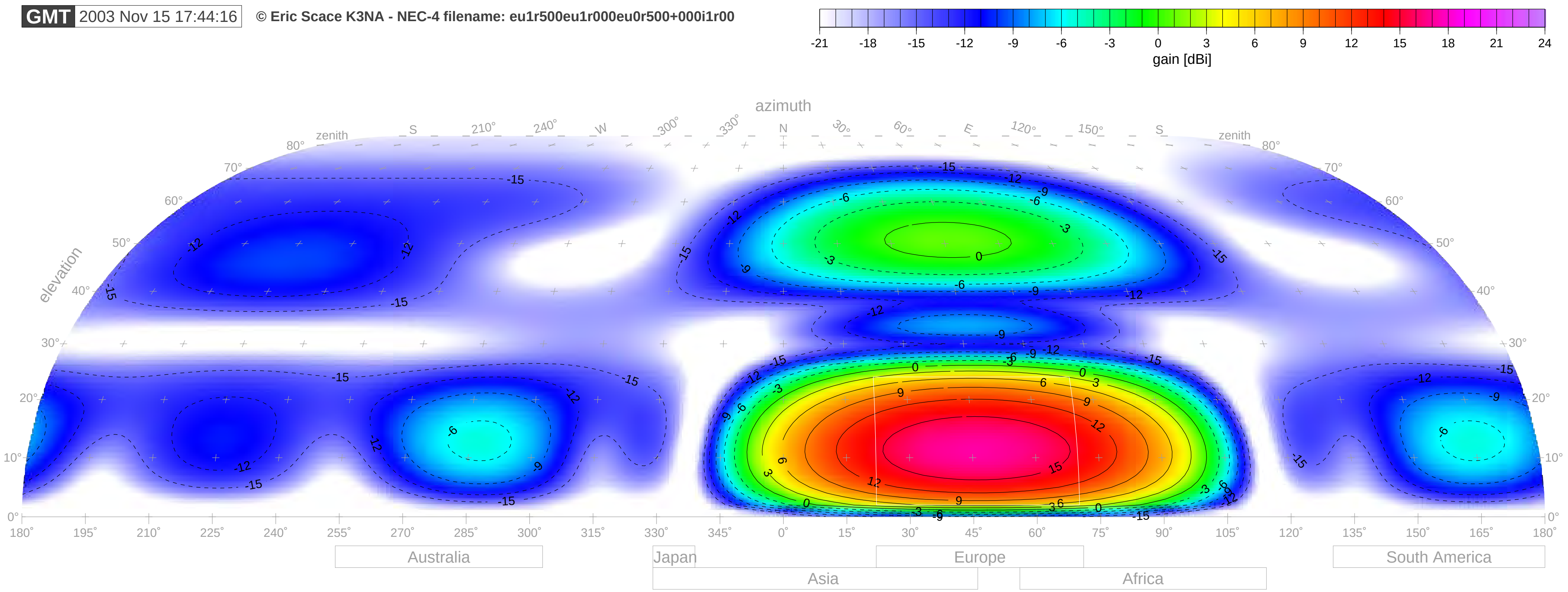
Target 1 - Europe_20m_from_W3: 22- 70° az 2-24° el.
   Median gain*: +13.37 dBi. Avg dev: +1.88 above, -3.52 below.
   Min: -2.03 dBi at 69° az 23° el.   Max: +16.70 dBi at 46° az 10° el.

Target 2 not used.

Non-targeted area statistics:
   Median gain*: -13.73 dBi. Avg dev: +14.90 above, -1.16 below.
   Min: -59.71 dBi at 116° az 0° el.   Max: +14.16 dBi at 70° az 10° el.

* Gain floor for calculating median, mean and deviation is -15.0 dBi.
NEC x-axis is North azimuth.

Figure 9 - Same stack as in Figure 8 with current tapering.   Weak sidelobes expand across the sky without significantly suppressing the upper half of the split main beam.



Optimize heights and current taper.
3 antennas present:
Eu20top Yagi20648 Height: 1.500 wavelngth. 46° azimuth. <-- Feedpoint # 1
Eu20mid Yagi20648 Height: 1.000 wavelngth. 46° azimuth. <-- Feedpoint # 2
Eu20bot Yagi20648 Height: 0.500 wavelngth. 46° azimuth. <-- Feedpoint # 3
Card deck created 03 Nov 15 Sat 17:43:28 -0500

NEC version 4.1

K3NA NOUTrim v3.7 2003 Jul 21 Mon

14.025 MHz

finite ground. sommerfeld solution
13.0 dielectric constant
5.0 mS/m

Drive impedance; voltage or current:
#1: 28.6 - j 10.2 Ω 1.000A ∠ -90.0°
#2: 26.2 - j 3.7 Ω 1.000A ∠ -90.0°
#3: 27.9 - j 9.8 Ω 1.000A ∠ -90.0°

Maximum gain: +17.20 dBi at 46° az 11° el.
88.4 % power efficiency.

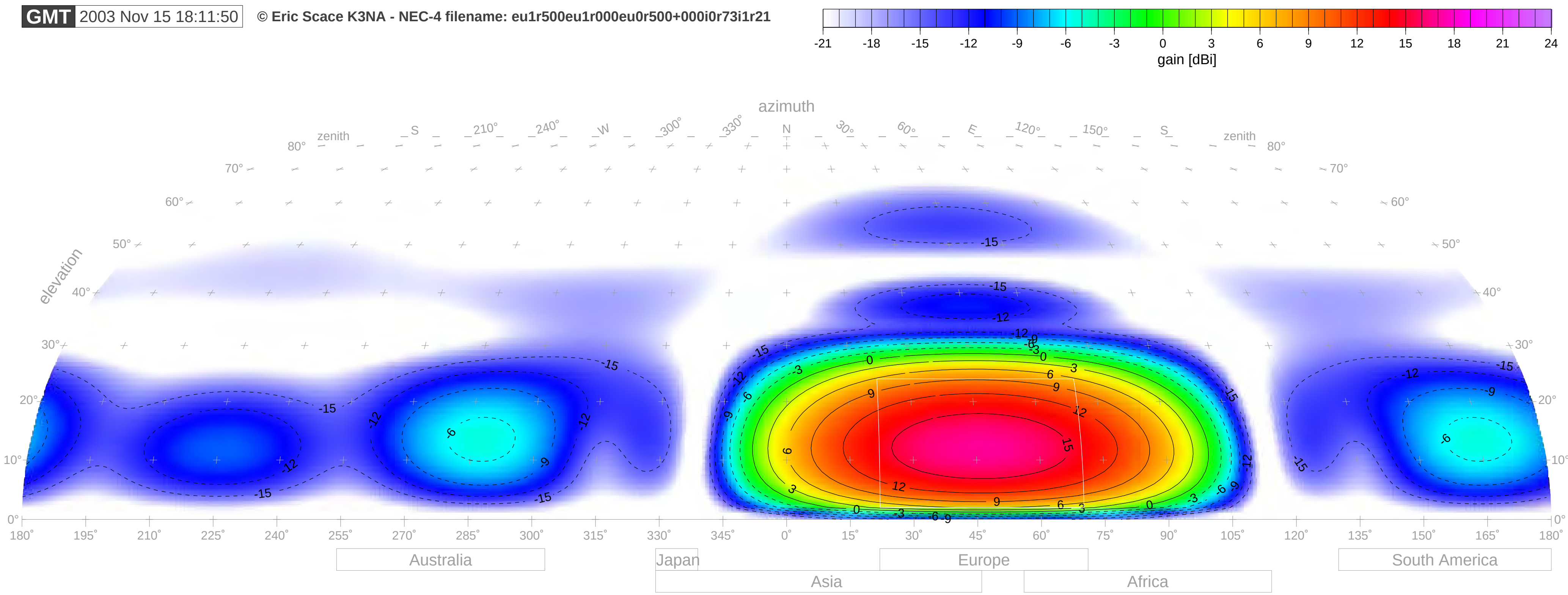
Target 1 - Europe_20m_from_W3: 22- 70° az 2-24° el.
Median gain*: +14.05 dBi. Avg dev: +1.74 above, -2.99 below.
Min: +3.93 dBi at 69° az 23° el. Max: +17.20 dBi at 46° az 11° el.

Target 2 not used.

Non-targeted area statistics:
Median gain*: -14.15 dBi. Avg dev: +14.36 above, -0.80 below.
Min: -50.40 dBi at 337° az 0° el. Max: +14.56 dBi at 70° az 10° el.

* Gain floor for calculating median, mean and deviation is -15.0 dBi.
NEC x-axis is North azimuth.

Figure 10 - Three-Yagi stack mounted 1½λ, 1λ and ½λ above ground, fed in phase with equal currents.



Optimize heights and current taper.
3 antennas present:
Eu20top Yagi20648 Height: 1.500 wavelngth. 46° azimuth. <-- Feedpoint # 1
Eu20mid Yagi20648 Height: 1.000 wavelngth. 46° azimuth. <-- Feedpoint # 2
Eu20bot Yagi20648 Height: 0.500 wavelngth. 46° azimuth. <-- Feedpoint # 3
Card deck created 03 Nov 15 Sat 18:11:02 -0500

NEC version 4.1

K3NA NOUTrim v3.7 2003 Jul 21 Mon

14.025 MHz

finite ground. sommerfeld solution
13.0 dielectric constant
5.0 mS/m

Drive impedance; voltage or current:
#1: 28.3 - j 7.3 Ω 0.730A ∠ -90.0°
#2: 26.8 - j 7.0 Ω 1.210A ∠ -90.0°
#3: 27.4 - j 7.9 Ω 1.000A ∠ -90.0°

Maximum gain: +16.96 dBi at 46° az 12° el.
87.9 % power efficiency.

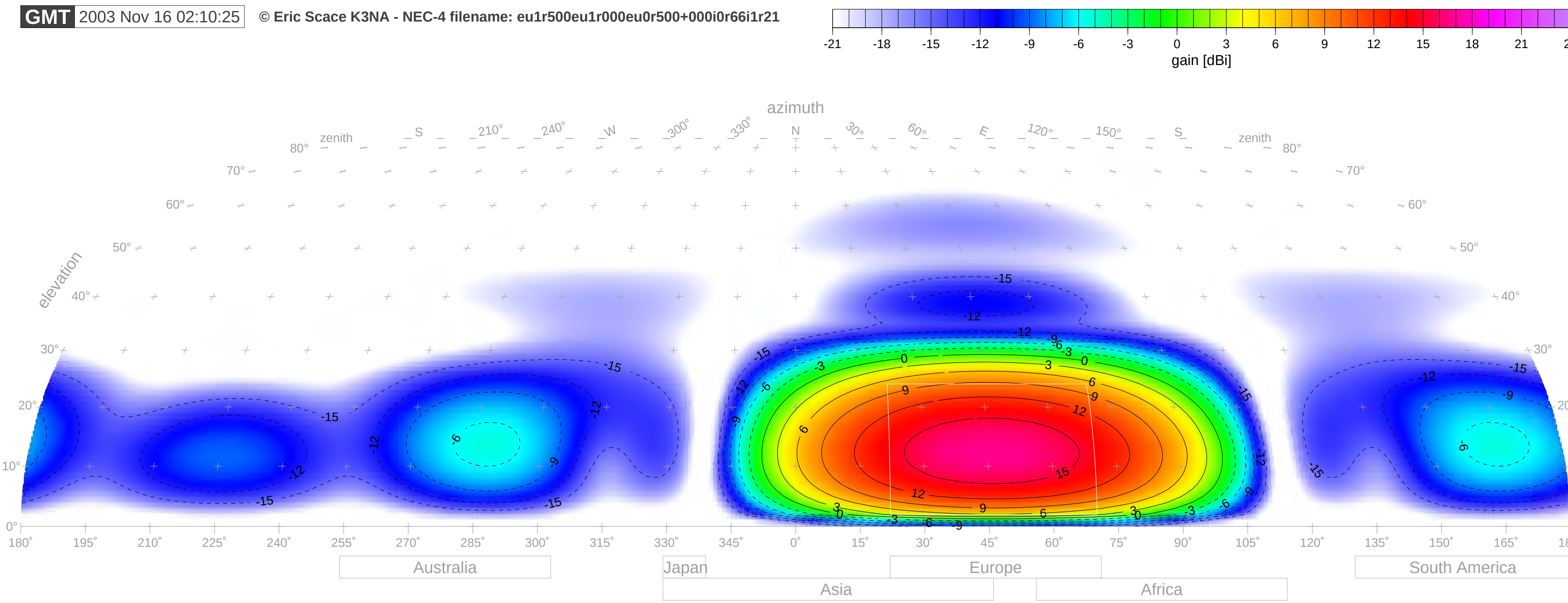
Target 1 - Europe_20m_from_W3: 22- 70° az 2-24° el.
Median gain*: +14.08 dBi. Avg dev: +1.57 above, -2.53 below.
Min: +4.94 dBi at 70° az 2° el. Max: +16.96 dBi at 46° az 12° el.

Target 2 not used.

Non-targeted area statistics:
Median gain*: -15.00 dBi. Avg dev: +16.56 above, +0.00 below.
Min: -56.89 dBi at 338° az 0° el. Max: +14.28 dBi at 70° az 11° el.

* Gain floor for calculating median, mean and deviation is -15.0 dBi.
NEC x-axis is North azimuth.

Figure 11 - Same stack as in Figure 10 with 0.73 (top) and 1.21 (middle) current tapering. Signals above 30° elevation reduced substantially. Corners of the target stronger by +1 dB.



Optimize heights and current taper.
3 antennas present:
Eu20top Yagi20648 Height: 1.500 wavelngth. 46° azimuth. <-- Feedpoint # 1
Eu20mid Yagi20648 Height: 1.000 wavelngth. 46° azimuth. <-- Feedpoint # 2
Eu20bot Yagi20648 Height: 0.500 wavelngth. 46° azimuth. <-- Feedpoint # 3
Card deck created 03 Nov 16 Sun 02:09:37 -0500

NEC version 4.1

K3NA NOUTrim v3.7 2003 Jul 21 Mon

14.025 MHz

finite ground. sommerfeld solution
13.0 dielectric constant
5.0 mS/m

Drive impedance; voltage or current:
#1: 28.3 - j 6.7 Ω 0.660A ∠ -90.0°
#2: 26.9 - j 7.3 Ω 1.210A ∠ -90.0°
#3: 27.3 - j 7.7 Ω 1.000A ∠ -90.0°

Maximum gain: +16.87 dBi at 47° az 12° el.
87.7 % power efficiency.

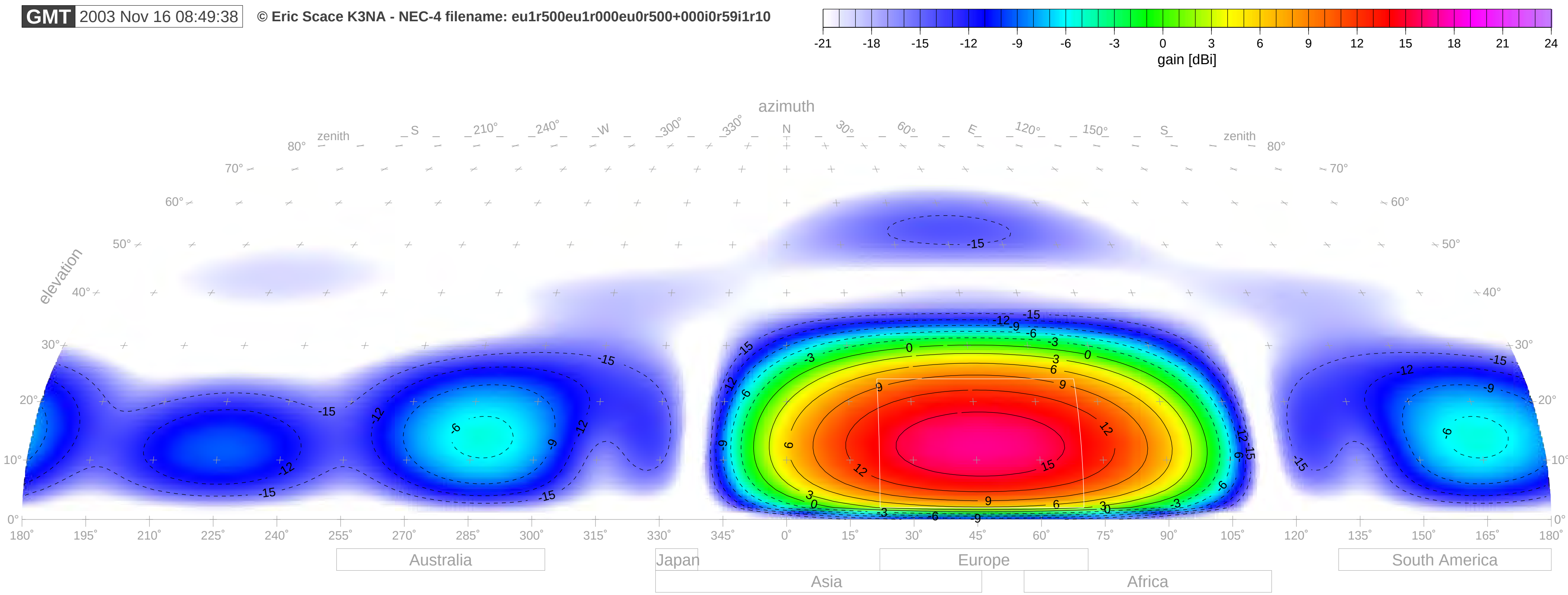
Target 1 - Europe_20m_from_W3: 22- 70° az 2-24° el.
Median gain*: +14.04 dBi. Avg dev: +1.54 above, -2.44 below.
Min: +4.72 dBi at 70° az 2° el. Max: +16.87 dBi at 47° az 12° el.

Target 2 not used.

Non-targeted area statistics:
Median gain*: -15.00 dBi. Avg dev: +16.65 above, +0.00 below.
Min: -60.16 dBi at 338° az 0° el. Max: +14.17 dBi at 70° az 11° el.

* Gain floor for calculating median, mean and deviation is -15.0 dBi.
NEC x-axis is North azimuth.

Figure 12 - Same stack as in Figure 10 with 0.66 (top) and 1.21 (middle) current tapering. Gain at any elevation above 45° is below -15 dBi.



Optimize heights and current taper.
3 antennas present:
Eu20top Yagi20648 Height: 1.500 wavelngth. 46° azimuth. <-- Feedpoint # 1
Eu20mid Yagi20648 Height: 1.000 wavelngth. 46° azimuth. <-- Feedpoint # 2
Eu20bot Yagi20648 Height: 0.500 wavelngth. 46° azimuth. <-- Feedpoint # 3
Card deck created 03 Nov 16 Sun 08:48:50 -0500

NEC version 4.1

K3NA NOUTrim v3.7 2003 Jul 21 Mon

14.025 MHz

finite ground. sommerfeld solution
13.0 dielectric constant
5.0 mS/m

Drive impedance; voltage or current:
#1: 28.5 - j 7.0 Ω 0.590A ∠ -90.0°
#2: 26.8 - j 6.9 Ω 1.100A ∠ -90.0°
#3: 27.3 - j 8.1 Ω 1.000A ∠ -90.0°

Maximum gain: +16.78 dBi at 47° az 12° el.
87.5 % power efficiency.

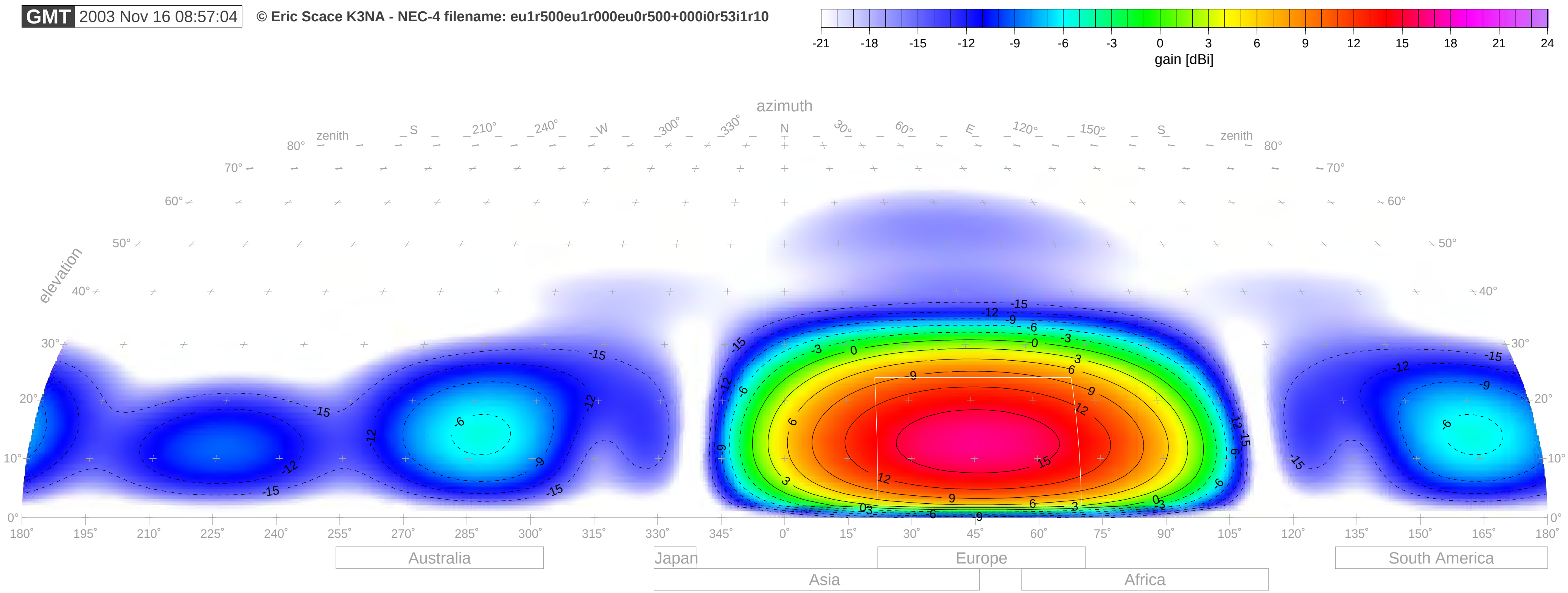
Target 1 - Europe_20m_from_W3: 22- 70° az 2-24° el.
Median gain*: +14.06 dBi. Avg dev: +1.44 above, -2.41 below.
Min: +4.55 dBi at 70° az 2° el. Max: +16.78 dBi at 47° az 12° el.

Target 2 not used.

Non-targeted area statistics:
Median gain*: -15.00 dBi. Avg dev: +16.75 above, +0.00 below.
Min: -58.73 dBi at 338° az 0° el. Max: +14.07 dBi at 21° az 12° el.

* Gain floor for calculating median, mean and deviation is -15.0 dBi.
NEC x-axis is North azimuth.

Figure 13 - Same stack as in Figure 10 with 0.59 (top) and 1.10 (middle) current tapering. Gain at any elevation above 36° is below -15 dBi.



Optimize heights and current taper.
3 antennas present:
Eu20top Yagi20648 Height: 1.500 wavelngth. 46° azimuth. <-- Feedpoint # 1
Eu20mid Yagi20648 Height: 1.000 wavelngth. 46° azimuth. <-- Feedpoint # 2
Eu20bot Yagi20648 Height: 0.500 wavelngth. 46° azimuth. <-- Feedpoint # 3
Card deck created 03 Nov 16 Sun 08:56:16 -0500

NEC version 4.1

K3NA NOUTrim v3.7 2003 Jul 21 Mon

14.025 MHz

finite ground. sommerfeld solution
13.0 dielectric constant
5.0 mS/m

Drive impedance; voltage or current:
#1: 28.5 - j 6.3 Ω 0.530A ∠ -90.0°
#2: 26.9 - j 7.2 Ω 1.100A ∠ -90.0°
#3: 27.3 - j 7.9 Ω 1.000A ∠ -90.0°

Maximum gain: +16.68 dBi at 47° az 12° el.
87.3 % power efficiency.

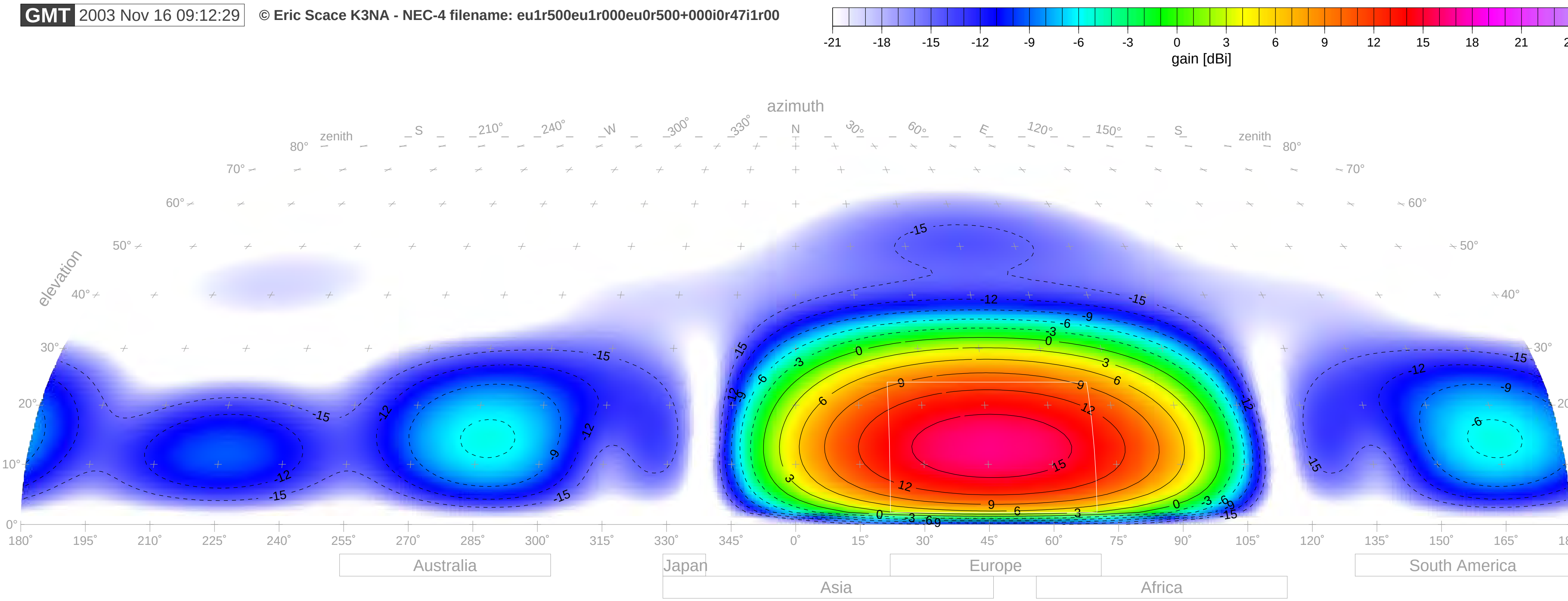
Target 1 - Europe_20m_from_W3: 22- 70° az 2-24° el.
Median gain*: +14.02 dBi. Avg dev: +1.41 above, -2.35 below.
Min: +4.31 dBi at 70° az 2° el. Max: +16.68 dBi at 47° az 12° el.

Target 2 not used.

Non-targeted area statistics:
Median gain*: -15.00 dBi. Avg dev: +16.78 above, +0.00 below.
Min: -59.59 dBi at 114° az 0° el. Max: +13.97 dBi at 21° az 12° el.

* Gain floor for calculating median, mean and deviation is -15.0 dBi.
NEC x-axis is North azimuth.

Figure 14 - Same stack as in Figure 10 with 0.53 (top) and 1.10 (middle) current tapering. Gain above 38° elevation is below -18 dBi. Outside the main lobe this stack is extremely quiet.



Optimize heights and current taper.
3 antennas present:
 Eu20top Yagi20648 Height: 1.500 wavelngth. 46° azimuth. <-- Feedpoint # 1
 Eu20mid Yagi20648 Height: 1.000 wavelngth. 46° azimuth. <-- Feedpoint # 2
 Eu20bot Yagi20648 Height: 0.500 wavelngth. 46° azimuth. <-- Feedpoint # 3
Card deck created 03 Nov 16 Sun 09:11:41 -0500

NEC version 4.1

K3NA NOUTrim v3.7 2003 Jul 21 Mon

14.025 MHz

finite ground. sommerfeld solution
 13.0 dielectric constant
 5.0 mS/m

Drive impedance; voltage or current:
#1: 28.8 - j 6.6 Ω 0.470A ∠ -90.0°
#2: 26.8 - j 6.8 Ω 1.000A ∠ -90.0°
#3: 27.3 - j 8.3 Ω 1.000A ∠ -90.0°

Maximum gain: +16.56 dBi at 47° az 12° el.
87.0 % power efficiency.

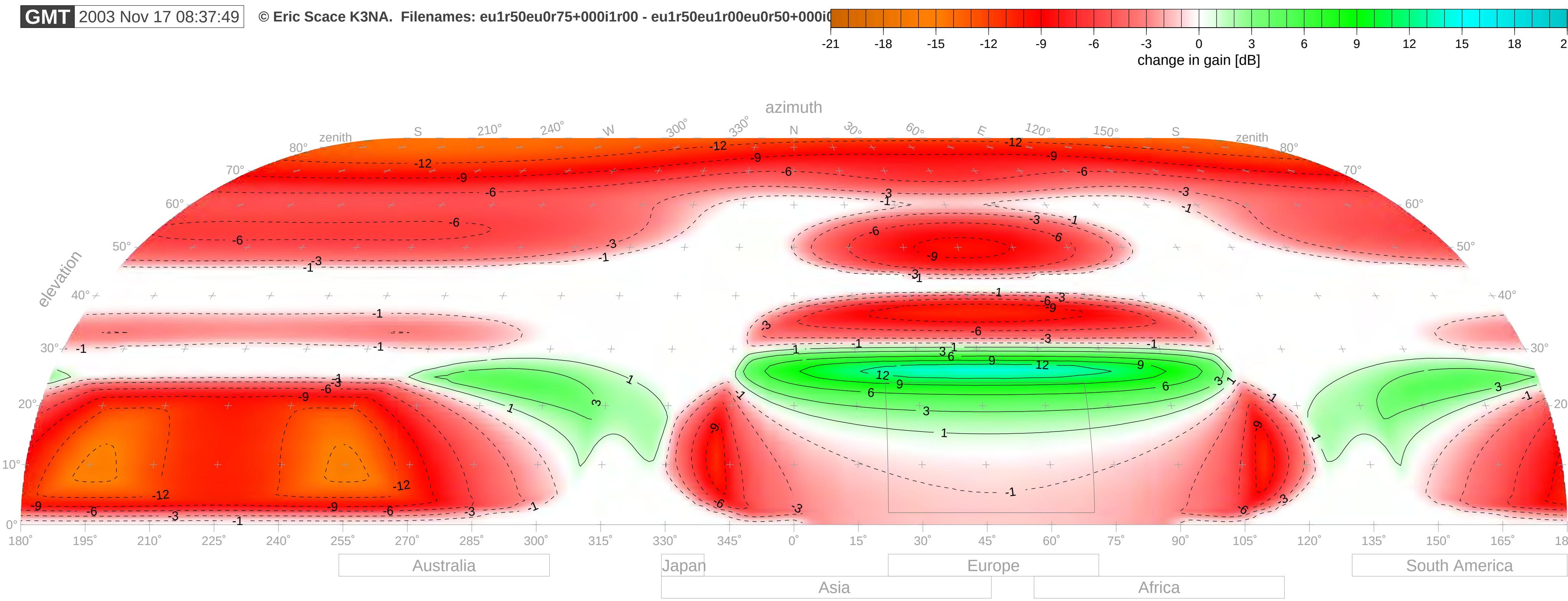
Target 1 - Europe_20m_from_W3: 22- 70° az 2-24° el.
 Median gain*: +13.91 dBi. Avg dev: +1.42 above, -2.24 below.
 Min: +4.09 dBi at 70° az 2° el. Max: +16.56 dBi at 47° az 12° el.

Target 2 not used.

Non-targeted area statistics:
 Median gain*: -15.00 dBi. Avg dev: +16.50 above, +0.00 below.
 Min: -57.97 dBi at 338° az 0° el. Max: +13.85 dBi at 21° az 12° el.

* Gain floor for calculating median, mean and deviation is -15.0 dBi.
NEC x-axis is North azimuth.

Figure 15 - Same stack as in Figure 10 with 0.47 (top) and 1.00 (middle) current tapering. Sidelobes at elevations above 38° are starting to reappear.



Optimize heights and current taper.
2 antennas present:
Eu20mid Yagi20648 Height: 1.500 wavelngth. 46° azimuth. <-- Feed
Eu20bot Yagi20648 Height: 0.750 wavelngth. 46° azimuth. <-- Feed
Card deck created 03 Nov 15 Sat 16:29:30 -0500

NEC version 4.1

K3NA NOUTrim v3.7 2003 Jul 21 Mon

Optimize heights and current taper.
3 antennas present:
Eu20top Yagi20648 Height: 1.500 wavelngth. 46° azimuth. <-- Feed
Eu20mid Yagi20648 Height: 1.000 wavelngth. 46° azimuth. <-- Feed
Eu20bot Yagi20648 Height: 0.500 wavelngth. 46° azimuth. <-- Feed
Card deck created 03 Nov 16 Sun 08:56:16 -0500

NEC version 4.1

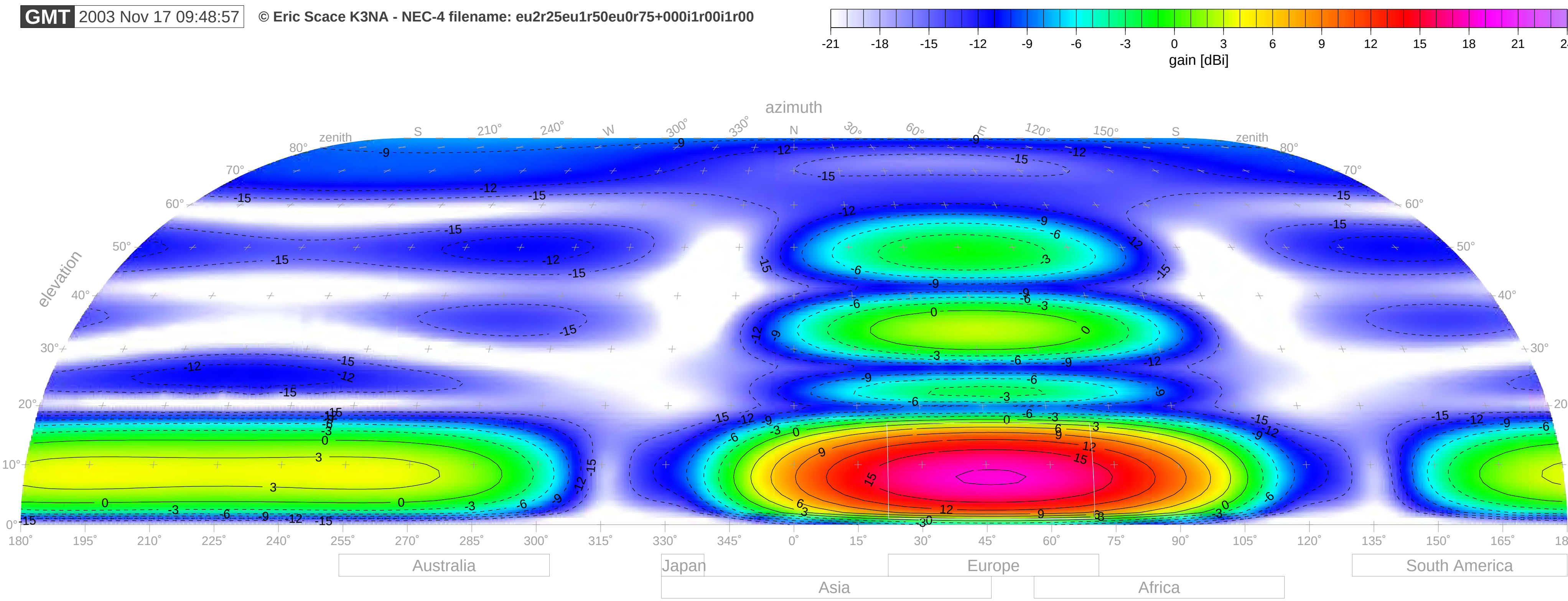
K3NA NOUTrim v3.7 2003 Jul 21 Mon

Target 1 - Europe_20m_from_W3: 22- 70° az 2-24° el.
Largest decrease: -1.53 dB at 70° az 2° el.
Largest increase: +8.82 dB at 45° az 23° el.
Median difference: +0.10 dB.

Non-targeted area statistics:
Largest decrease: -15.74 dB at 255° az 8° el.
Largest increase: +14.41 dB at 46° az 26° el.
Median difference: -1.97 dB.

* Gain floor for calculating differences is -15.0 dBi.
NEC x-axis is North azimuth.
Statistics computed by AEGBin v1.2 - 2003 Nov 15 Sat.

Figure 16 - Pattern difference between two-Yagi stack mounted at 1½λ and ¾λ with no current taper, and the three-Yagi current-tapered stack of Figure 14.



Optimize heights and current taper.
3 antennas present:
 Eu20top Yagi20648 Height: 2.250 wavelngth. 46° azimuth. <-- Feedpoint # 1
 Eu20mid Yagi20648 Height: 1.500 wavelngth. 46° azimuth. <-- Feedpoint # 2
 Eu20bot Yagi20648 Height: 0.750 wavelngth. 46° azimuth. <-- Feedpoint # 3
Card deck created 03 Nov 17 Mon 09:48:08 -0500

NEC version 4.1

K3NA NOUTrim v3.7 2003 Jul 21 Mon

14.025 MHz

finite ground. sommerfeld solution
 13.0 dielectric constant
 5.0 mS/m

Drive impedance; voltage or current:
#1: 28.2 - j 6.4 Ω 1.000A ∠ -90.0°
#2: 30.3 - j 2.3 Ω 1.000A ∠ -90.0°
#3: 28.6 - j 5.4 Ω 1.000A ∠ -90.0°

Maximum gain: +18.24 dBi at 46° az 7° el.
89.9 % power efficiency.

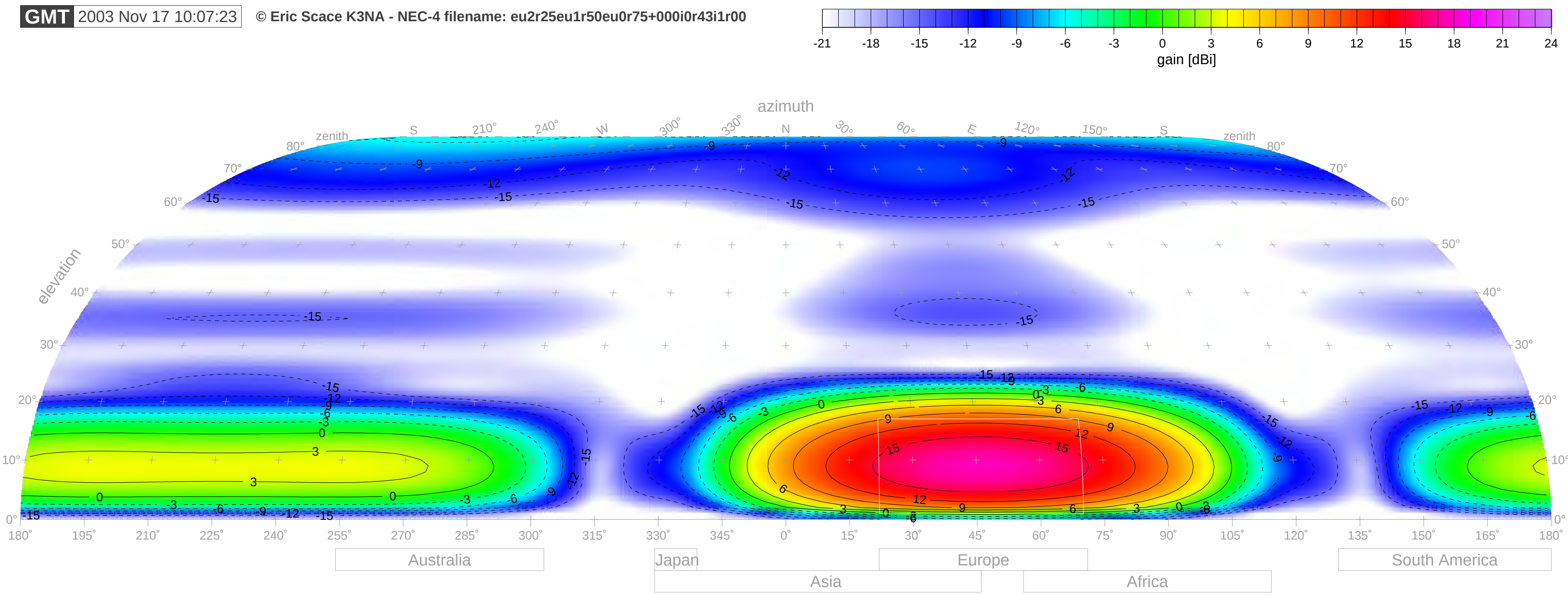
Target 1 - Europe_20m_from_W3_at_opening: 22- 70° az 1-17° el.
 Median gain*: +14.82 dBi. Avg dev: +1.99 above, -3.40 below.
 Min: +3.41 dBi at 69° az 16° el. Max: +18.24 dBi at 46° az 7° el.

Target 2 not used.

Non-targeted area statistics:
 Median gain*: -13.02 dBi. Avg dev: +14.30 above, -1.69 below.
 Min: -52.76 dBi at 216° az 32° el. Max: +15.84 dBi at 70° az 7° el.

* Gain floor for calculating median, mean and deviation is -15.0 dBi.
NEC x-axis is North azimuth.

Figure 17 - A typical three-Yagi stack mounted at 2¼λ, 1½λ and ¾λ heights; no current taper. Target zone redefined to lower elevation angles for band openings and closings: 1 to 17°.



Optimize heights and current taper.
3 antennas present:
 Eu20top Yagi20648   Height: 2.250 wavelngth. 46° azimuth.   <-- Feedpoint # 1
 Eu20mid Yagi20648   Height: 1.500 wavelngth. 46° azimuth.   <-- Feedpoint # 2
 Eu20bot Yagi20648   Height: 0.750 wavelngth. 46° azimuth.   <-- Feedpoint # 3
Card deck created 03 Nov 17 Mon 10:06:34 -0500

NEC version 4.1

K3NA NOUTrim v3.7 2003 Jul 21 Mon

14.025 MHz

finite ground. sommerfeld solution
   13.0 dielectric constant
   5.0 mS/m

Drive impedance; voltage or current:
#1: 27.5 - j 2.1 Ω   0.430A ∠ -90.0°
#2: 29.5 - j 3.9 Ω   1.000A ∠ -90.0°
#3: 29.6 - j 5.7 Ω   1.000A ∠ -90.0°

Maximum gain: +17.58 dBi at 47° az 8° el.
88.4 % power efficiency.

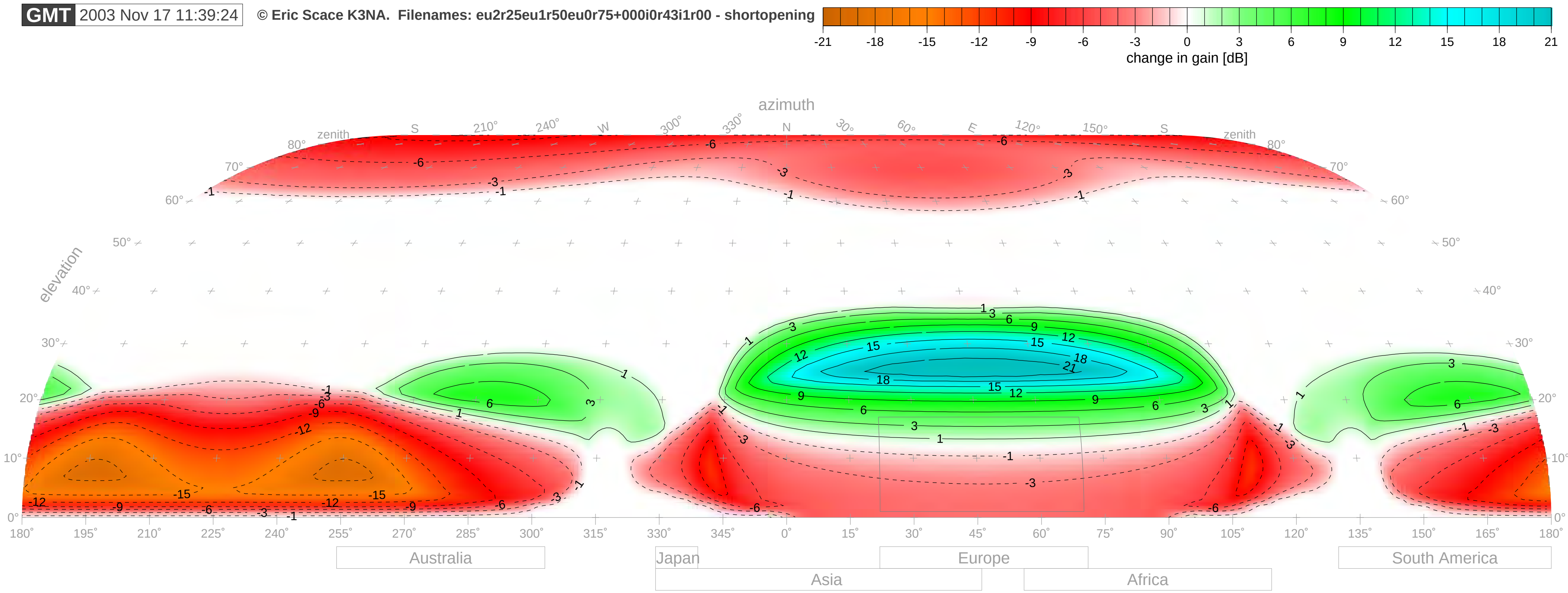
Target 1 - Europe_20m_from_W3_at_opening: 22- 70° az 1-17° el.
   Median gain*: +14.86 dBi. Avg dev: +1.51 above, -2.54 below.
   Min: +4.05 dBi at 70° az 1° el.   Max: +17.58 dBi at 47° az 8° el.

Target 2 not used.

Non-targeted area statistics:
   Median gain*: -15.00 dBi. Avg dev: +16.81 above, +0.00 below.
   Min: -39.68 dBi at 105° az 44° el.   Max: +15.15 dBi at 21° az 8° el.

* Gain floor for calculating median, mean and deviation is -15.0 dBi.
NEC x-axis is North azimuth.

Figure 18 - Same three-Yagi stack as in Figure 17 with current taper of 0.43 : 1.00 : 1.00 (top to bottom).



Optimize heights and current taper.
3 antennas present:
Eu20top Yagi20648 Height: 2.250 wavelngth. 46° azimuth. <-- Feed
Eu20mid Yagi20648 Height: 1.500 wavelngth. 46° azimuth. <-- Feec
Eu20bot Yagi20648 Height: 0.750 wavelngth. 46° azimuth. <-- Feed
Card deck created 03 Nov 17 Mon 10:06:34 -0500

NEC version 4.1

K3NA NOUTrim v3.7 2003 Jul 21 Mon

Optimize heights and current taper.
3 antennas present:
Eu20top Yagi20648 Height: 1.500 wavelngth. 46° azimuth. <-- Feed
Eu20mid Yagi20648 Height: 1.000 wavelngth. 46° azimuth. <-- Feec
Eu20bot Yagi20648 Height: 0.500 wavelngth. 46° azimuth. <-- Feed
Card deck created 03 Nov 17 Mon 11:26:54 -0500

NEC version 4.1

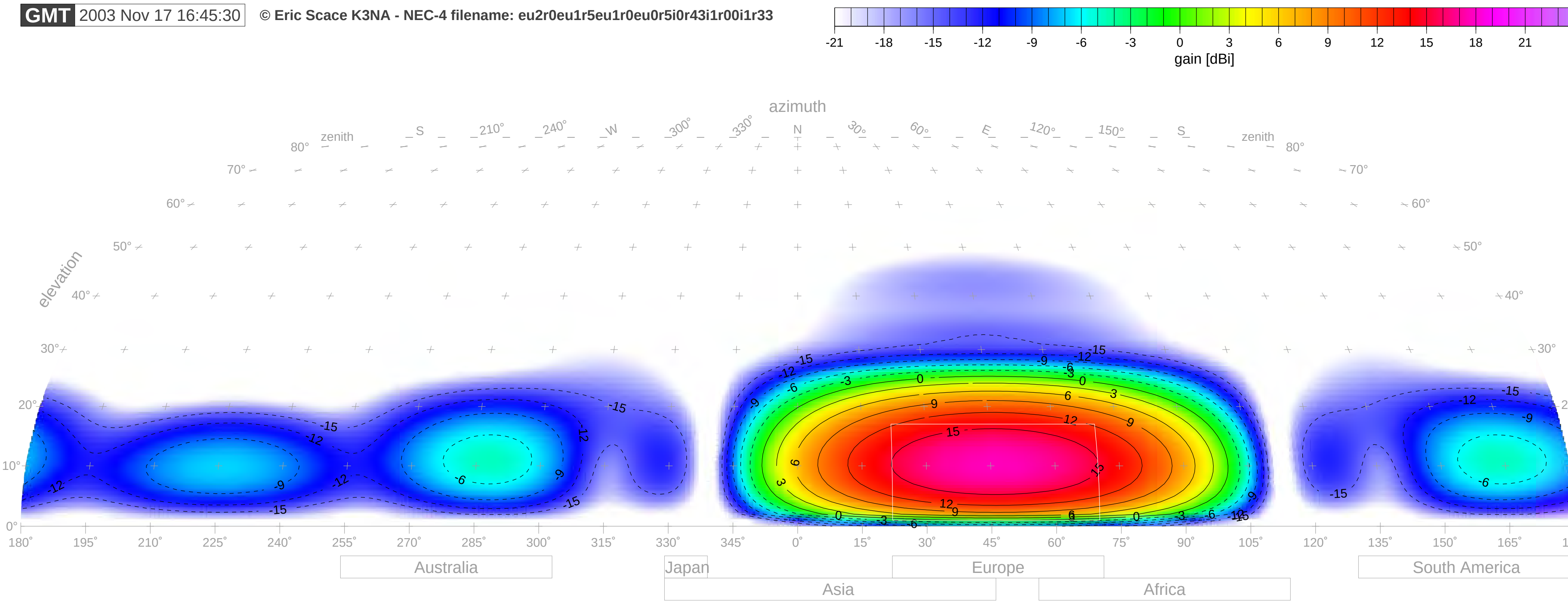
K3NA NOUTrim v3.7 2003 Jul 21 Mon

Target 1 - Europe_20m_from_W3_at_opening: 22- 70° az 1-17° el.
Largest decrease: -4.03 dB at 70° az 1° el.
Largest increase: +4.22 dB at 49° az 16° el.
Median difference: -1.96 dB.

Non-targeted area statistics:
Largest decrease: -18.74 dB at 255° az 8° el.
Largest increase: +23.52 dB at 46° az 25° el.
Median difference: +0.00 dB.

* Gain floor for calculating differences is -15.0 dBi.
NEC x-axis is North azimuth.
Statistics computed by AEGBin v1.2 - 2003 Nov 15 Sat.

Figure 19 - Comparing current-tapered tall and short 3-Yagi stacks (Figures 18 and 14). The short stack is cleaner in zenith and rear but down -3 to -4 dB at low target elevations.



Optimize heights and current taper.
4 antennas present:
Eu20top Yagi20648 Height: 2.000 wavelngth. 46° azimuth. <-- Feedpoint # 1
Eu20hi Yagi20648 Height: 1.500 wavelngth. 46° azimuth. <-- Feedpoint # 2
Eu20mid Yagi20648 Height: 1.000 wavelngth. 46° azimuth. <-- Feedpoint # 3
Eu20bot Yagi20648 Height: 0.500 wavelngth. 46° azimuth. <-- Feedpoint # 4
Card deck created 03 Nov 17 Mon 16:44:25 -0500

NEC version 4.1

K3NA NOUTrim v4.0 2003 Nov 17 Mon

14.025 MHz

finite ground. sommerfeld solution
13.0 dielectric constant
5.0 mS/m

Drive impedance; voltage or current:
#1: 28.3 - j 6.3 Ω 0.430A ∠ -90.0°
#2: 27.5 - j 7.2 Ω 1.000A ∠ -90.0°
#3: 27.2 - j 7.1 Ω 1.330A ∠ -90.0°
#4: 27.4 - j 7.7 Ω 1.000A ∠ -90.0°

Maximum gain: +17.68 dBi at 45° az 10° el.
89.2 % power efficiency.

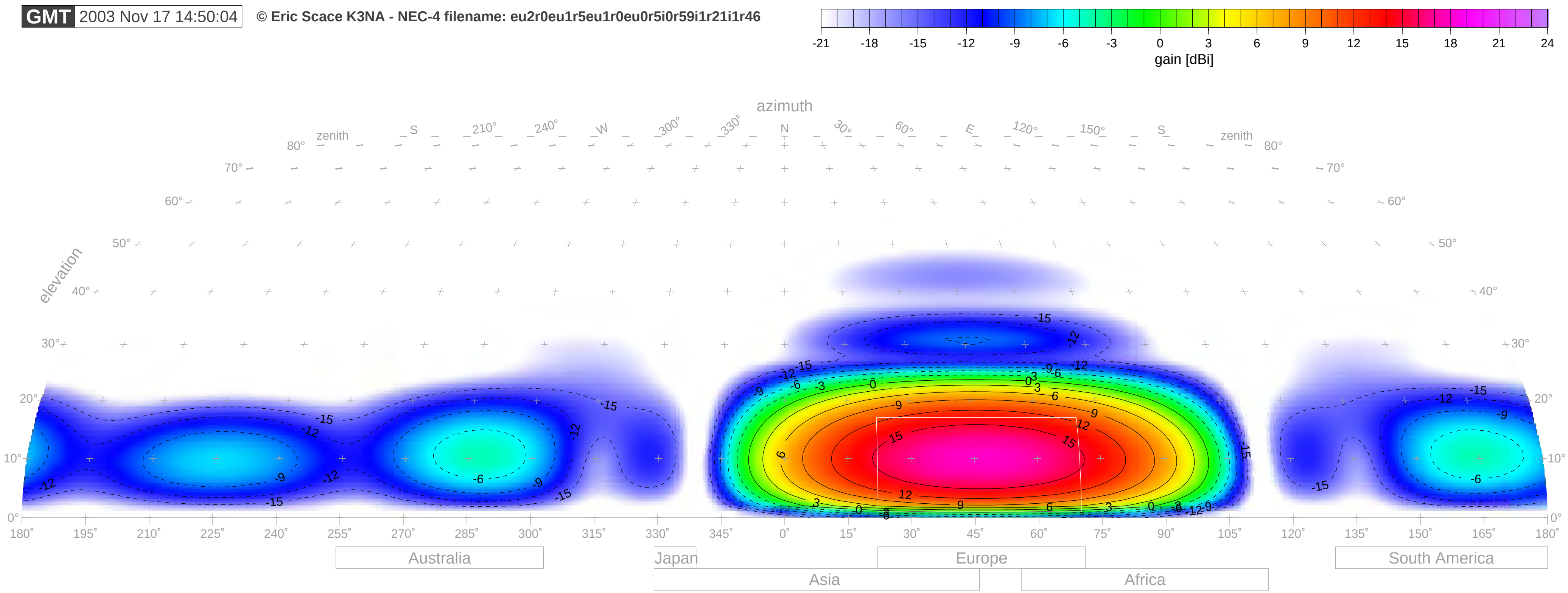
Target 1 - Europe_20m_from_W3_at_opening: 22- 70° az 1-17° el.
Median gain*: +15.25 dBi. Avg dev: +1.28 above, -2.43 below.
Min: +2.63 dBi at 70° az 1° el. Max: +17.68 dBi at 45° az 10° el.

Target 2 not used.

Non-targeted area statistics:
Median gain*: -15.00 dBi. Avg dev: +18.12 above, +0.00 below.
Min: -60.05 dBi at 113° az 0° el. Max: +15.00 dBi at 70° az 10° el.

* Gain floor for calculating median, mean and deviation is -15.0 dBi.
Points at or below floor: 13854, 67.2% of sky.
NEC x-axis is North azimuth.

Figure 20 - Four-Yagi stack mounted at 2λ, 1½λ, 1λ and ½λ with current taper ratios of 0.43 : 1.00 : 1.33 : 1.00 (top to bottom).



Optimize heights and current taper.
4 antennas present:
Eu20top Yagi20648 Height: 2.000 wavelngth. 46° azimuth. <-- Feedpoint # 1
Eu20hi Yagi20648 Height: 1.500 wavelngth. 46° azimuth. <-- Feedpoint # 2
Eu20mid Yagi20648 Height: 1.000 wavelngth. 46° azimuth. <-- Feedpoint # 3
Eu20bot Yagi20648 Height: 0.500 wavelngth. 46° azimuth. <-- Feedpoint # 4
Card deck created 03 Nov 17 Mon 14:48:59 -0500

NEC version 4.1

K3NA NOUTrim v4.0 2003 Nov 17 Mon

14.025 MHz

finite ground. sommerfeld solution
13.0 dielectric constant
5.0 mS/m

Drive impedance; voltage or current:
#1: 28.2 - j 6.8 Ω 0.590A ∠ -90.0°
#2: 27.3 - j 7.2 Ω 1.210A ∠ -90.0°
#3: 27.3 - j 7.2 Ω 1.460A ∠ -90.0°
#4: 27.5 - j 7.4 Ω 1.000A ∠ -90.0°

Maximum gain: +17.89 dBi at 46° az 9° el.
89.6 % power efficiency.

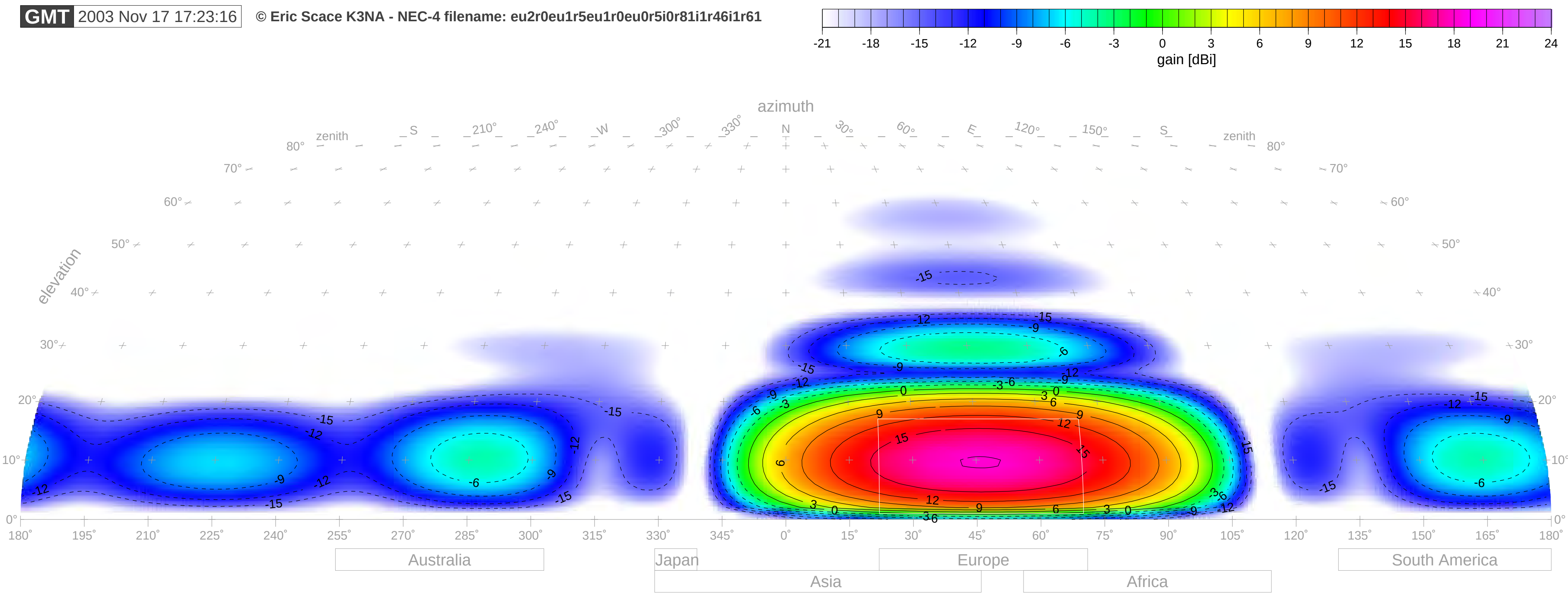
Target 1 - Europe_20m_from_W3_at_opening: 22- 70° az 1-17° el.
Median gain*: +15.35 dBi. Avg dev: +1.36 above, -2.40 below.
Min: +3.14 dBi at 70° az 1° el. Max: +17.89 dBi at 46° az 9° el.

Target 2 not used.

Non-targeted area statistics:
Median gain*: -15.00 dBi. Avg dev: +17.82 above, +0.00 below.
Min: -58.67 dBi at 339° az 0° el. Max: +15.21 dBi at 70° az 10° el.

* Gain floor for calculating median, mean and deviation is -15.0 dBi.
Points at or below floor: 13832, 67.1% of sky.
NEC x-axis is North azimuth.

Figure 21 - Same as Figure 20 except taper of 0.59 : 1.21 : 1.46 : 1.00. Increasing upper antenna currents lowers main beam's elevation, but causes very small grating lobes above it.



Optimize heights and current taper.
4 antennas present:
Eu20top Yagi20648 Height: 2.000 wavelngth. 46° azimuth. <-- Feedpoint # 1
Eu20hi Yagi20648 Height: 1.500 wavelngth. 46° azimuth. <-- Feedpoint # 2
Eu20mid Yagi20648 Height: 1.000 wavelngth. 46° azimuth. <-- Feedpoint # 3
Eu20bot Yagi20648 Height: 0.500 wavelngth. 46° azimuth. <-- Feedpoint # 4
Card deck created 03 Nov 17 Mon 17:22:10 -0500

NEC version 4.1

K3NA NOUTrim v4.0 2003 Nov 17 Mon

14.025 MHz

finite ground. sommerfeld solution
13.0 dielectric constant
5.0 mS/m

Drive impedance; voltage or current:
#1: 28.1 - j 7.3 Ω 0.810A ∠ -90.0°
#2: 27.2 - j 7.0 Ω 1.460A ∠ -90.0°
#3: 27.4 - j 7.4 Ω 1.610A ∠ -90.0°
#4: 27.6 - j 7.0 Ω 1.000A ∠ -90.0°

Maximum gain: +18.11 dBi at 46° az 9° el.
89.9 % power efficiency.

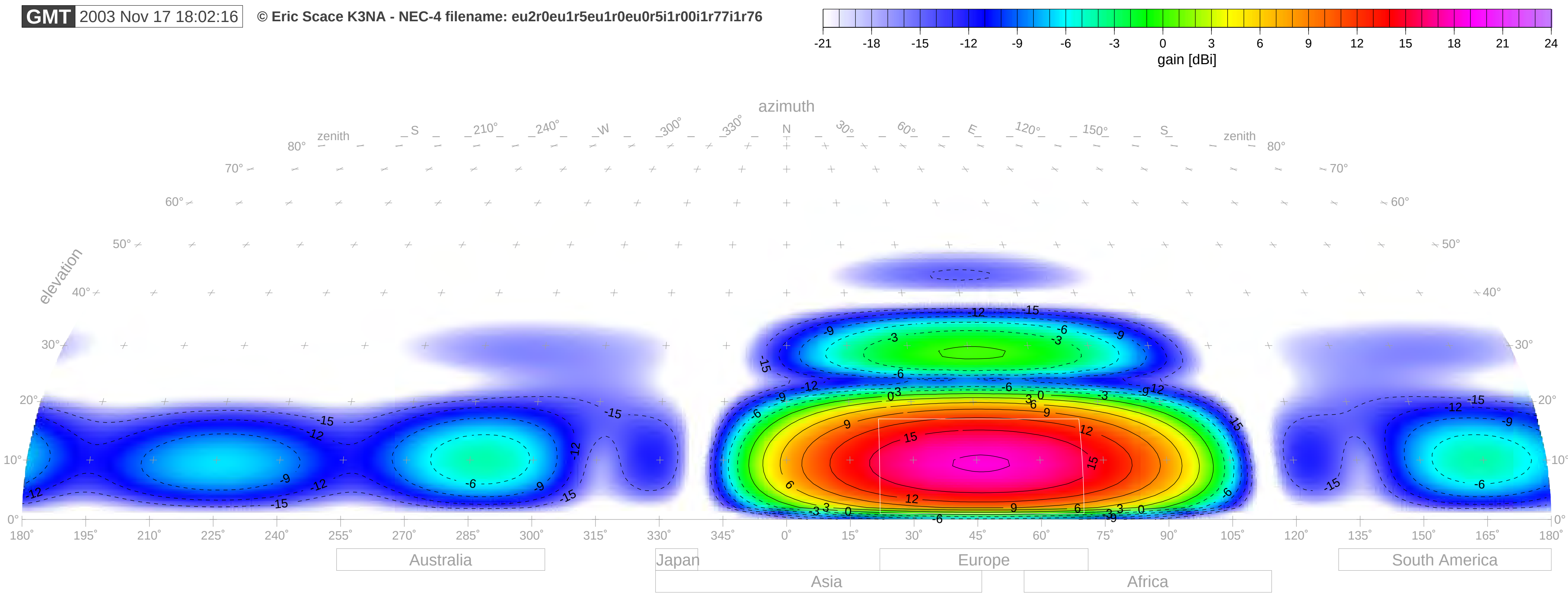
Target 1 - Europe_20m_from_W3_at_opening: 22- 70° az 1-17° el.
Median gain*: +15.47 dBi. Avg dev: +1.40 above, -2.49 below.
Min: +3.61 dBi at 70° az 1° el. Max: +18.11 dBi at 46° az 9° el.

Target 2 not used.

Non-targeted area statistics:
Median gain*: -15.00 dBi. Avg dev: +17.57 above, +0.00 below.
Min: -54.20 dBi at 339° az 0° el. Max: +15.37 dBi at 70° az 10° el.

* Gain floor for calculating median, mean and deviation is -15.0 dBi.
Points at or below floor: 13808, 66.9% of sky.
NEC x-axis is North azimuth.

Figure 22 - Same as Figure 21 except taper 0.81 : 1.46 : 1.61 : 1.00. Main beam lower and louder. Increased target sector peak, median, and minimum gains. Grating lobes intensify.



Optimize heights and current taper.
4 antennas present:
Eu20top Yagi20648 Height: 2.000 wavelngth. 46° azimuth. <-- Feedpoint # 1
Eu20hi Yagi20648 Height: 1.500 wavelngth. 46° azimuth. <-- Feedpoint # 2
Eu20mid Yagi20648 Height: 1.000 wavelngth. 46° azimuth. <-- Feedpoint # 3
Eu20bot Yagi20648 Height: 0.500 wavelngth. 46° azimuth. <-- Feedpoint # 4
Card deck created 03 Nov 17 Mon 18:01:12 -0500

NEC version 4.1

K3NA NOUTrim v4.0 2003 Nov 17 Mon

14.025 MHz

finite ground. sommerfeld solution
13.0 dielectric constant
5.0 mS/m

Drive impedance; voltage or current:
#1: 28.0 - j 7.0 Ω 1.000A ∠ -90.0°
#2: 27.1 - j 7.3 Ω 1.770A ∠ -90.0°
#3: 27.4 - j 7.3 Ω 1.760A ∠ -90.0°
#4: 27.7 - j 6.8 Ω 1.000A ∠ -90.0°

Maximum gain: +18.21 dBi at 46° az 9° el.
90.0 % power efficiency.

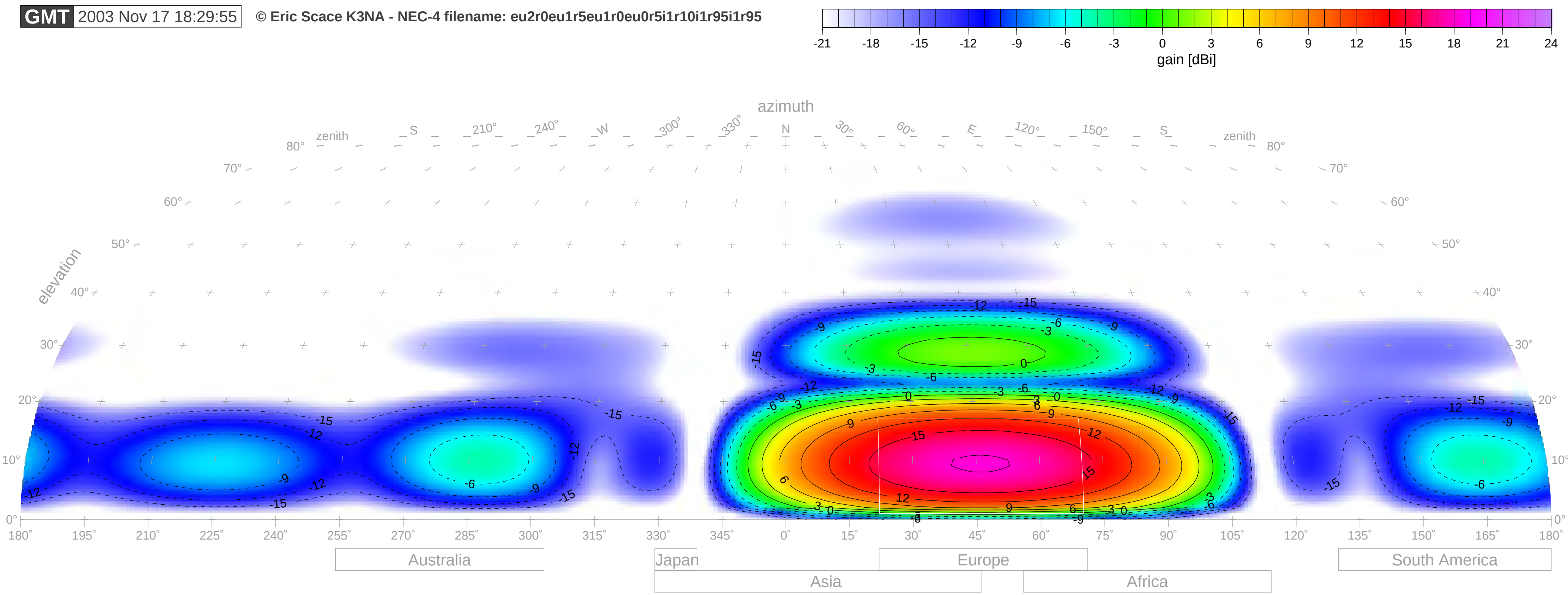
Target 1 - Europe_20m_from_W3_at_opening: 22- 70° az 1-17° el.
Median gain*: +15.47 dBi. Avg dev: +1.47 above, -2.53 below.
Min: +3.86 dBi at 70° az 1° el. Max: +18.21 dBi at 46° az 9° el.

Target 2 not used.

Non-targeted area statistics:
Median gain*: -15.00 dBi. Avg dev: +17.41 above, +0.00 below.
Min: -53.24 dBi at 339° az 0° el. Max: +15.43 dBi at 21° az 9° el.

* Gain floor for calculating median, mean and deviation is -15.0 dBi.
Points at or below floor: 13695, 66.4% of sky.
NEC x-axis is North azimuth.

Figure 23 - Same as Figure 22 except taper of 1.00 : 1.77 : 1.77 : 1.00. Target sector peak and minimum gains increase slightly, but the grating lobe above main beam grows +6 dB.



Optimize heights and current taper.
4 antennas present:
Eu20top Yagi20648 Height: 2.000 wavelngth. 46° azimuth. <-- Feedpoint # 1
Eu20hi Yagi20648 Height: 1.500 wavelngth. 46° azimuth. <-- Feedpoint # 2
Eu20mid Yagi20648 Height: 1.000 wavelngth. 46° azimuth. <-- Feedpoint # 3
Eu20bot Yagi20648 Height: 0.500 wavelngth. 46° azimuth. <-- Feedpoint # 4
Card deck created 03 Nov 17 Mon 18:28:51 -0500

NEC version 4.1

K3NA NOUTrim v4.0 2003 Nov 17 Mon

14.025 MHz

finite ground. sommerfeld solution
13.0 dielectric constant
5.0 mS/m

Drive impedance; voltage or current:
#1: 28.0 - j 7.2 Ω 1.100A ∠ -90.0°
#2: 27.1 - j 7.1 Ω 1.950A ∠ -90.0°
#3: 27.4 - j 7.6 Ω 1.950A ∠ -90.0°
#4: 27.8 - j 6.2 Ω 1.000A ∠ -90.0°

Maximum gain: +18.22 dBi at 46° az 9° el.
90.0 % power efficiency.

Target 1 - Europe_20m_from_W3_at_opening: 22- 70° az 1-17° el.
Median gain*: +15.47 dBi. Avg dev: +1.47 above, -2.54 below.
Min: +3.89 dBi at 70° az 1° el. Max: +18.22 dBi at 46° az 9° el.

Target 2 not used.

Non-targeted area statistics:
Median gain*: -15.00 dBi. Avg dev: +17.35 above, +0.00 below.
Min: -53.11 dBi at 339° az 0° el. Max: +15.43 dBi at 21° az 9° el.

* Gain floor for calculating median, mean and deviation is -15.0 dBi.
Points at or below floor: 13588, 65.9% of sky.
NEC x-axis is North azimuth.

Figure 24 - Same as Figure 23 except taper 1.10 : 1.95 : 1.95 : 1.00. Target sector peak, median, and minimum gains stopped improving but the grating lobe continues to expand.