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A Study of Outrigger Antenna Configurations

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Abstract

This memo analyzes the effectiveness of using one or two outrigger antennas placed along the lab road combined with 6 or 5 antennas in the conventional "T" configuration. Each configuration is evaluated for three source models at declinations of -20, +15, and +50 degrees. UV tracks are generated for each model, and inverted with uniform weighting to yield a beam. Plots of the UV coverage and beam shape are presented for each potential configuration. Maximum negative sidelobe level and beam size are used to evaluate the quality of the configuration. The optimal location for a single outrigger antenna appears to be at a distance 1570N (feet) and 340E. The optimal location for a second outrigger appears to be at a distance of 2800N. If this location is not practical, a suitable alternate location is at 2440N 220W. These configurations yield sub-arcsecond resolutions with beam sidelobes levels approaching the 10% level for a full track.

1 Introduction

Substantial improvement in the BIMA Array spatial resolution can be achieved with minimum additional cost by placing elements of the expanded array at locations near the existing lab road. Expansion of the existing "T" in the East-West direction is also feasible, but would require additional cost in preparing a roadbed. Expansion on the North direction is impeded by existing rock outcrops.

2 Outrigger Positions and Models

A total of 8 outrigger antenna positions are considered. These positions lie along the service road and are summarized in Table 1 and fig. 1. The positions are numbered according to a survey conducted by A. Grossman. For historical reasons, the list begins with o3 because positions o1 and o2 are too close to the "T" to yield useful configurations. The configurations are analyzed for three source models described in Table 2.

Table 1: Outrigger antenna positions

Position	North (ft)	East (ft)	Description
o3	1440	480	W of road 400 meters from lab
o4	1470	600	E of road 400 meters from lab
o5	1570	340	W of road near utility pole
o6	1700	450	E of road across from o5
o7	1880	320	E of road
o8	2100	100	W of road
o9	2340	-220	W of road near gas pump
o10	2800	0	E of road and south of shop on Bidwell's land

Table 2: Source model parameters

Source	Freq	Dec.	HA range
1	100GHz	-20	± 3.5
2	100GHz	$+15$	± 4.7
3	100GHz	$+50$	± 6.0

3 Configuration Analysis

First a standard 6-element "T" configuration is analyzed. This serves as a basis for comparison with outrigger configurations. Next, configurations consisting of 5 or 6 elements on the "T" and one or two outrigger antennas are considered. In each case, a UV coverage is calculated for the three source parameters described in Table 2. This UV coverage is inverted with uniform weighting to yield a beam. The central part of each beam is fit to a two dimensional Gaussian in order to estimate the resolution. The full-width at half-maximum of the Gaussian is reported in arcseconds on the major and minor axes as Bmaj and Bmin. The position angle of the major axis, measured counter-clockwise from North, is reported as Bpa. Also, the maximum negative sidelobe level is reported as as a percentage in SLneg.

The Gaussian fit to the beam and the maximum negative sidelobe provide a quantitative estimate of the configuration quality. However, not all configurations can be assessed on the basis of these numbers. In this case, plots of the UV coverage and beam contours must be consulted. It is clear from studying the beam contours, that one also needs to consider to what extent the beam deviates from a Gaussian shape, and what are the shapes and distribution of positive and negative sidelobes.

3.1 A Standard 6-element "T" configuration

First a standard 6-element A configuration is analyzed for comparison. Antennas are positioned at 500W, 380W, 180E, 500E, 380N, and 580N. The results are summarized in Table 3. The resulting UV coverage and beam contours are show in figs. 2a–c.

3.2 Configurations with 1 Outrigger

Next a 7 element configuration consisting of 1 outrigger is analyzed. Antennas on the T are configured at 500W, 80E, 500E, 260N, 440N, and 580N. The results are summarized in Table 4 and figs. 3-5.

Examination of the table shows that positions o3, o4, and o5, yield the minimum sidelobe levels with a reasonable spatial resolution. The contour plots of the beam shapes show that the super-resolution available in positions o6 and o7 (and by analogy o8 and o9) is obtained at the cost of creating an irregular beam shape. Thus these outer positions, including o8 and o9, will not be considered further. Of the three remaining positions (o3, o4 or o5), o5 produces the minimum sidelobe level at positive declinations and similar resolution at all three positions. For negative declinations, the sidelobe level is slightly higher (compared with o3 and o4), however, the beam shape shows less of an elongated shoulder and provides slightly greater resolution. Thus, position o5 seems to yield the best compromise between sidelobe structure and resolution for all three test declinations. Position o4 is the next best alternative, if o5 turns out to be impractical for other reasons.

3.3 Configurations 2 Outriggers

Next a 7 element configuration consisting of 2 outrigger is analyzed making the assumption that the first outrigger is positioned at o5. Antennas on the T are positioned at 500W, 240W, 500E, 440N, and 580N. Results are summarized in Table 5 and figs. 6-9. Here, the results are clear: position o10 yields the lowest sidelobe level with the highest resolution. Examination of the beam shapes, also supports this conclusion. In fact, the beams for o9 and o10 are quite similar in sidelobe structure and shape. And although the beam exhibits extensive sidelobe structure for low declinations, this is more a consequence of the poor coverage available for low declinations sources rather than specific outrigger position. In case position o10 is not available, o9 seems a suitable alternate.

4 Summary

Position o5 is clearly the optimum position for a single outrigger antenna in conjunction with 6 elements on the "T". To clarify, position o5 is near where the utility poles make their closest approach to the road and where the speed limit sign is posted. Examination of figs. 3-5 shows that at positions beyond o5, large gaps appear in the UV coverage, and this degrades the beam shape. The optimal position for a second outrigger in a configuration with o5 and 5 elements on the "T" is near position o10.

Additional considerations in determining site locations involve signal and power distribution to these sites, and ease of transport. These considerations are beyond the scope of this memo, and may be considered in an additional report.

Table 3: Results for configuration A6

Dec	Figure	Sl neg (%)	Bmaj (asec)	Bmin (asec)	Bpa
−20	2a	-26	3.78	1.29	-01
+15	2b	-23	2.13	1.42	-05
+50	2c	-22	1.58	1.39	-08

Table 4: Results for configurations with 1 outrigger

Position	Dec	Figure	Sl neg (%)	Bmaj (asec)	Bmin (asec)	Bpa
o3	−20	3a	-18	1.98	1.17	-45
o4	−20	3b	-18	2.08	1.09	-43
o5	−20	3c	-19	1.78	1.18	-55
o6	−20	3d	-19	1.76	1.01	-55
o7	−20	3e	-23	1.57	0.98	-65
o3	+15	4a	-21	1.61	0.82	-75
o4	+15	4b	-20	1.56	0.77	-71
o5	+15	4c	-17	1.57	0.84	-79
o6	+15	4d	-22	1.49	0.71	-77
o7	+15	4e	-21	1.43	0.68	-83
o3	+50	5a	-13	1.25	0.82	-72
o4	+50	5b	-13	1.21	0.78	-68
o5	+50	5c	-11	1.24	0.79	-77
o6	+50	5d	-14	1.14	0.69	-73
o7	+50	5e	-14	1.12	0.69	-78

Table 5: Results for configurations with 2 outriggers, one fixed at position o5

Position	Dec	Figure	SL neg (%)	Bmaj (asec)	Bmin (asec)	Bpa
o7	−20	6a	34	1.63	0.81	-60
o8	−20	6b	27	1.50	0.80	-63
o9	−20	6c	28	1.27	0.80	-79
o10	−20	6d	17	1.29	0.70	-70
o7	+15	7a	37	1.29	0.53	-80
o8	+15	7b	28	1.24	0.54	-81
o9	+15	7c	27	1.17	0.49	-86
o10	+15	7d	21	1.13	0.45	-83
o7	+50	8a	28	0.99	0.56	-79
o8	+50	8b	23	0.96	0.55	-81
o9	+50	8c	18	0.91	0.51	-88
o10	+50	8d	14	0.86	0.47	-83