A 110m×100m Elliptical Station Design
Optimized to Minimize Side Lobes

Leonid Kogan (NRAO), Aaron Cohen (NRL)

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ABSTRACT

It has recently been decided that the dimensions of an LWA station will be 110m×100m elliptical, with a minimum separation between dipoles of 5.0 meters (see engineering notice EN0003). Here, we present a station configuration designed within these parameters to minimize the maximum sidelobe to be encountered during observations (not including mutual coupling effects). We present the general parameters of this design including beam size, sidelobe levels and power pattern as a function of frequency within the LWA operational bandwidth.

1. Background on LWA Station Design

It has long been agreed that an LWA station should consist of 256 phased dipoles spread over an area of roughly 100 meters. The factor driving the number of dipoles is the estimated collecting area required for ionospheric calibration (Cohen 2006; Ellingson 2008). The motivation for a 100 meter station size is a balance between the desire for a small field of view (to reduce sidelobe confusion and make ionospheric calibration easier) and practical limitations (obtaining land, and the costs of fencing and cabling).

The possibility of an elliptical station has been explored in order to enhance the performance towards both the far north and, especially, the scientifically important far south which includes the Galactic center and (at times) the Sun and Jupiter (Clarke 2007; Kogan et al 2008). However, simulations by Kuniyoshi et al (2008) showed that this could negatively affect observations at mid-latitudes for long time-synthesis imaging, for which a circular station would be optimal. Ultimately, a compromise solution was reached, in which an elliptical station with reduced axis ratio would be used. The dimensions were determined by the size of the land granted for each station site, and were determined to be an ellipse with a major axis of 110 meters in the north-south direction and a minor axis of 100 meters in the east-west direction.

The minimum allowed spacing was also set by a balance of two effects. The first effect is that as the minimum spacing increases, the freedom of placement of dipoles decreases and the maximum sidelobe increases. This effect had to be balanced against the goal of keeping the spacing large in order to reduce the effects of mutual coupling. It was found that for a spacing of 5.0 meters, the increase in sidelobes was still minimal, but raising it much further would result in a rapid rise in the sidelobes. Therefore this value was chosen as optimal.

2. Determining the Station Configuration

Previously, LWA station designs have been optimized to minimize the maximum sidelobe level throughout the visible sky according to the iterative approach described in (Kogan 2000). This same method was repeated here for a 110m×100m ellipse with 5.0-meter minimum spacing between dipoles. For an array phased to zenith, the optimization should minimize sidelobes all the way to the horizons by optimizing in a circle defined by the radius $|\sin(z)| \leq 1$, where z is the zenith angle. However, in typical observing mode, LWA stations could be phased to any location above the horizon, and the sidelobes should still be optimized anywhere else above the horizon. As describe in Kogan & Cohen (2005), this can still be done with a zenith pointing provided that the optimization radius is doubled. Therefore we have conducted all optimization within the radius of $|\sin(z)| \leq 2$. Though counterintuitive, this is mathematically equivalent to optimizing in the normal radius $|\sin(z)| \leq 1$ for any pointing above the horizon.

The resulting configuration is shown in Figure 1. This is also available in ASCII format on the LWA memo series website[1] at the same place this memo is posted.

3. Power Pattern

3.1. Sidelobes

The maximum sidelobe for this configuration is 1.62% (-17.9 dB), which is less than half the typical value for a "random" configuration, which is about 4% (-14.0 dB). The power pattern is plotted in 2-dimensions as a contour plot in Figure 2 and as 1-dimensional "slices" in Figure 3.

3.2. Beam Size

We have calculated the resulting beam size as a function of frequency. This is shown in Table 1 as the FWHM of the station beam along both the east-west and north-south axes. As can be seen, the axis ratio of the beam is about 1.06, which is a bit less than the axis ratio of the station geometry which is 1.1. This is because during optimization, the dipole positions shift somewhat from a perfectly uniform distribution.

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[1]http://www.ece.vt.edu/swe/lwa/#VTR

4. Conclusion

We present a station configuration optimized to minimize sidelobes for the final agreed upon parameters of an LWA station. The optimized station produces a maximum sidelobe of only 1.62% (-17.9 dB) throughout the sky for any phase center.

We should note, however, what was not taken into account in this study. First, we have not included the effects of mutual coupling. Second, we have not analyzed the effects of inevitable position errors in the placement of the dipoles within a station. Third, we have not analyzed the effect on the station power pattern of errors in the delay phases applied to each dipole. These factors will need to be better understood to enable the best possible operation of the station and to guide the design of the monitor and control systems.

REFERENCES

L. Kogan, "Optimizing a Large Array Configuration to Minimize the Side lobes", IEEE Transactions on Antennas and Propagation, vol 48, NO 7, July 2000, p 1075.

L. Kogan & A. Cohen, "Optimization of the LWA Antenna Station Configuration Minimizing Side Lobes", Long Wavelength Array Memo #21, May 5, 2005.

A. Cohen, "Estimated Collecting Area Needed for LWA Calibration", LWA Memo #52, August 30, 2006.

T. E. Clarke, "Scientific Requirements for the Long Wavelength Array Ver. 2.3", Long Wavelength Array Memo #117, Nov 19, 2007 (SRR approved version).

L. Kogan, A. Cohen, and E. Polisensky, "Elliptical LWA Station Configurations Optimized to Minimize Side Lobes", Long Wavelength Array Memo #139, June 24, 2008.

S. Ellingson, "System Parameters Affecting LWA Calibration (Memo 52 Redux)", LWA Memo #94, October 11, 2008.

M. Kuniyoshi, S. Bhatnagar, G. Taylor, and A. Cohen, "Shape of LWA Station: A Study of the Synthesized Beam Shapes and Weighting Scheme", Long Wavelength Array Memo #148, December 15, 2008.

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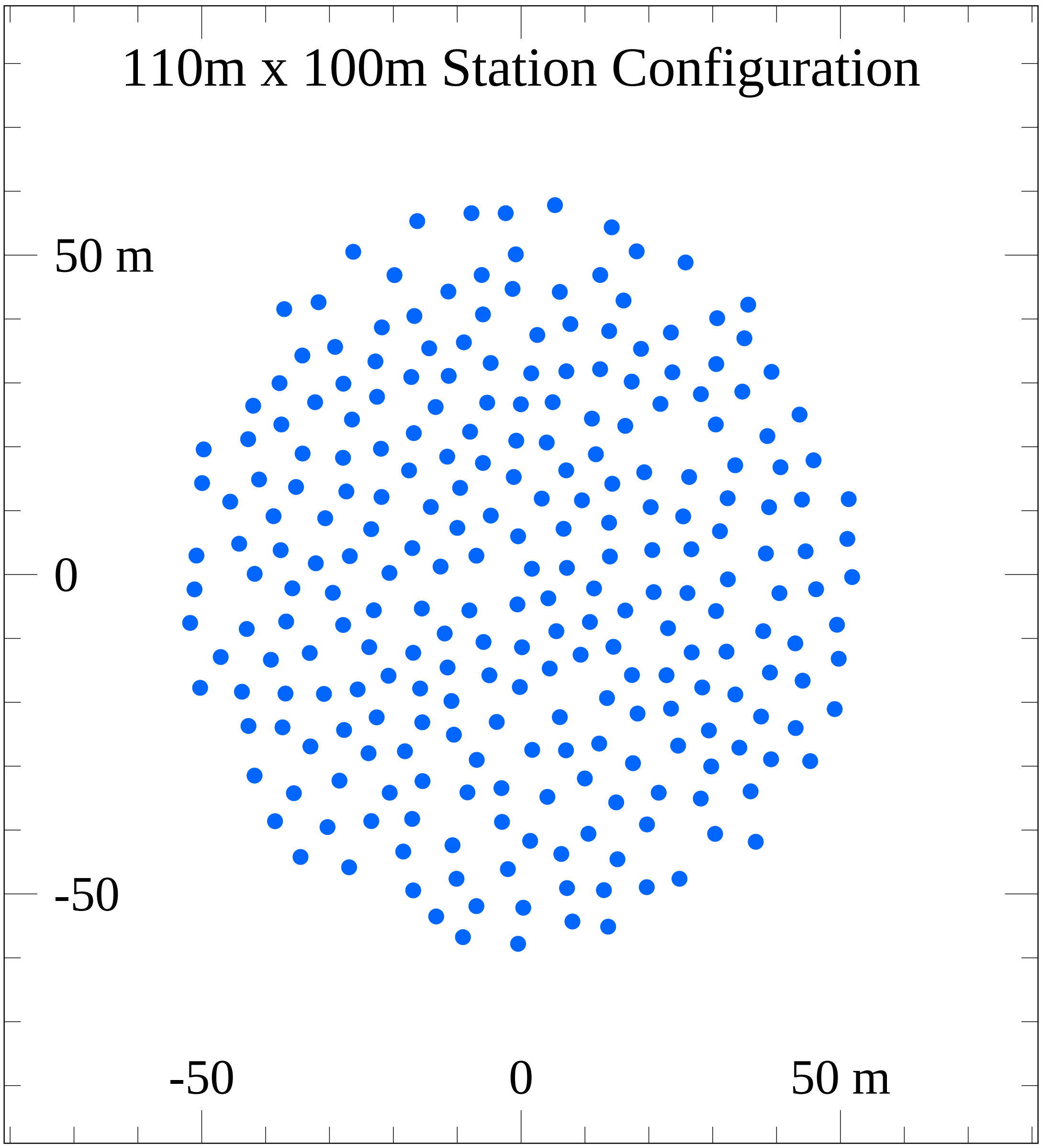

Fig. 1.— Elliptical station design with 256 elements optimized to minimize sidelobes across the entire sky at 80 MHz. The outer dimensions are 110m×100m and the minimum spacing between dipoles is 5.0 meters.

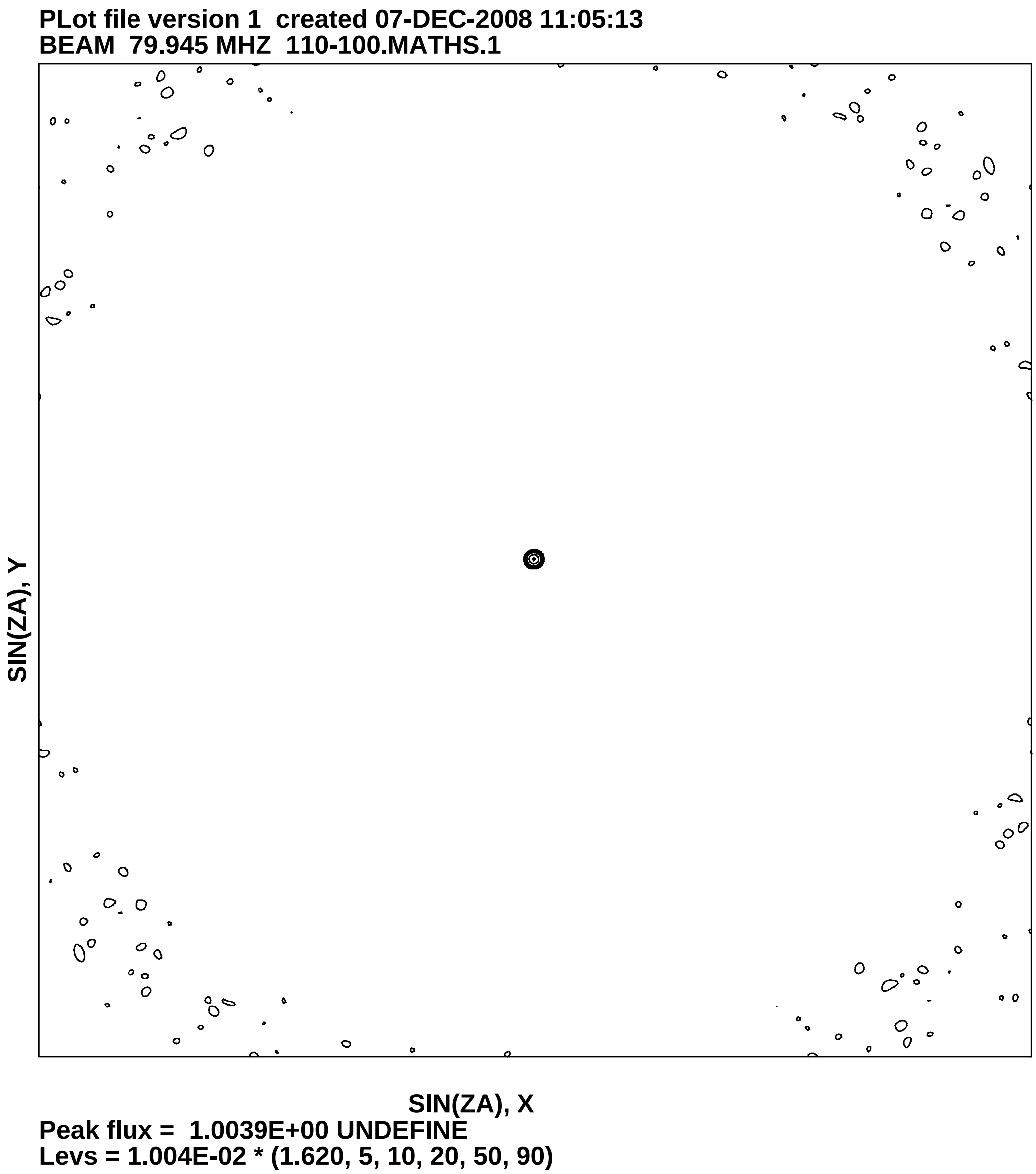

Fig. 2.— Power pattern at 80 MHz as a function of $\sin(z)$, where z is the zenith angle. The optimization is done for $|\sin(z)| \leq 2$, to include all possible differences between $\sin(z)$ for the phase center and the sidelobe location as described by Kogan & Cohen (2005). Within the optimized region, the maximum sidelobe is 1.62% (-17.9 dB).

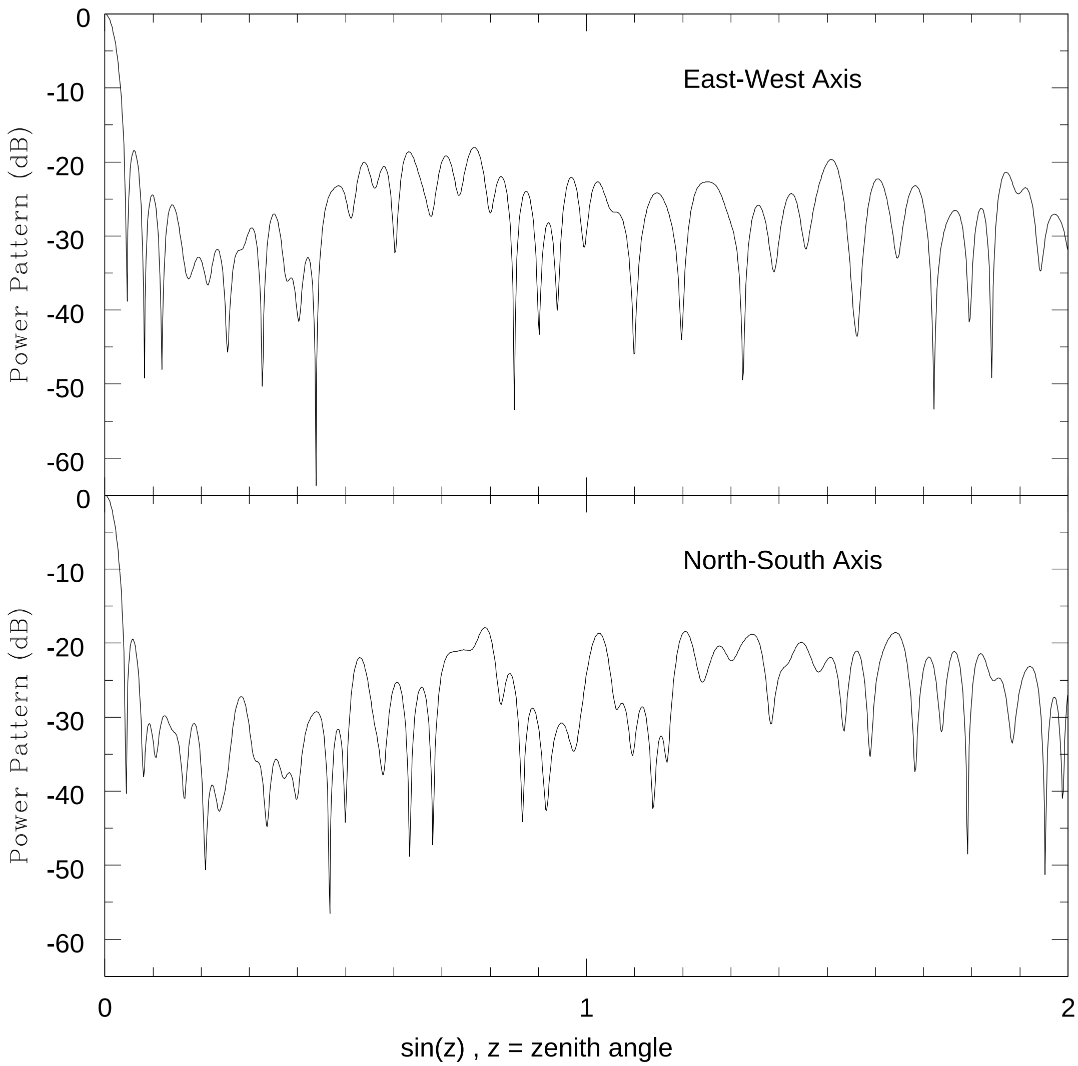

Fig. 3.— Power pattern at 80 MHz for slices along the north-south and east-west directions as a function of $\sin(z)$, where z is the zenith angle. Because the power pattern is symmetric about $\sin(z) = 0$, only one "side" of the power pattern is shown. The optimization is done for $|\sin(z)| \leq 2$, to include all possible differences between $\sin(z)$ for the phase center and the sidelobe location as described by Kogan & Cohen (2005). Within the optimized region, the maximum sidelobe is 1.62% (-17.9 dB).

ν (MHz)	FWHM (E-W axis) (deg)	FWHM (N-S axis) (deg)
10	17.60	16.61
12	14.65	13.83
14	12.55	11.84
16	10.97	10.36
18	9.75	9.20
20	8.77	8.28
22	7.97	7.53
24	7.31	6.90
26	6.75	6.37
28	6.26	5.91
30	5.85	5.52
32	5.48	5.17
34	5.16	4.87
36	4.87	4.60
38	4.61	4.36
40	4.38	4.14
42	4.17	3.94
44	3.98	3.76
46	3.81	3.60
48	3.65	3.45
50	3.51	3.31
52	3.37	3.18
54	3.25	3.07
56	3.13	2.96
58	3.02	2.85
60	2.92	2.76
62	2.83	2.67
64	2.74	2.59
66	2.66	2.51
68	2.58	2.43
70	2.50	2.36
72	2.43	2.30
74	2.37	2.24
76	2.31	2.18
78	2.25	2.12
80	2.19	2.07

Table 1: Beamsize at zenith as a function of observing frequency.