LWDA Ground Screen Performance Report

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Johnathan York, Aaron Kerkhoff, Greg Taylor, Stephanie Moats, Eduardo Gonzalez, Masaya Kuniyoshi

Introduction

On June 28, 2007 small ground screens were installed under each of the sixteen Long Wavelength Demonstrator Array antennas by a team consisting of Greg Taylor, Stephanie Moats, Eduardo Gonzalez, Masaya Kuniyoshi and Kurt Weiler. The motivation for an LWDA ground screen is based upon the work done by Nagini Paravatsu, et al and documented in LWA memo #90. This report documents the installation and performance of the LWDA ground screens, both predicted and as measured.

Installation

The LWDA ground screen is composed of a welded galvanized steel wire mesh purchased at Home Depot for $80 for a 100 foot roll, 5 feet wide. The strands going the length of the wire are spaced 2 inches apart, while cross−pieces are welded in place every 4 inches. This wire mesh is typically used for fencing. If stressed the welds can break, but since we only care about continuity lengthwise (along the 10 foot section as opposed to along the 5 foot wide crosspieces) this is acceptable.

We first cut the roll into ten 10 foot sections. One section was then placed under an LWDA antenna and a 4" notch was cut out from the middle to allow room for the mast. Next, another 10 foot section was placed on the other side of the antenna, again notched so as to fit around the mast and overlap with the first piece by 4". These two sheets were aligned by eye to have their lengthwise wires run parallel to the orientation of one set of blades. Two more 10 foot sections were then installed in a similar fashion perpendicular to the first two. In this way continuous lengthwise wires were established underneath both sets of dipoles covering an area of 9' x 9' with some variation due to the amount of overlap and length of sections. Finally, stakes were inserted at the corners and at the overlap to firmly hold the ground screen in place. Installation time improved as the day progressed (see Table 1), and could typically be done by a team of 3 people in about 10 minutes for each antenna stand. Installing the ground screen before the antenna is put in place would reduce the time spent to ~5 minutes, since much of the time spent is in the notching and maneuvering of the wire underneath the antenna.

The weather on the day of installation ranged from blazing sun to light rain, but we were fortunate that the lightning remained distant. The installation itself is further documented by the photos in Figure 1.

Figure 1: Installation of Ground Screens at the LWDA

In the interest of correlating against the measured data, the time of installation for each antenna was recorded and reproduced in Table 1.

Table 1: Installation Time For Each LWDA Antenna

Antenna	Start Time (MDT)	Complete Time (MDT)
1	10:30	10:50
2	10:50	11:10
3	11:15	11:35
4	11:35	11:45
5	11:45	12:05
6	12:10	12:25
7	13:15	13:25
8	13:30	13:45
9	13:45	13:53
10	13:55	14:07
11	14:07	14:22
12	14:40	14:52
13	14:52	14:59
14	14:52	14:59
15	15:00	15:07
16	15:15	15:25

Simulated Performance

Aaron Kerkhoff ran a number of NEC simulation to determine the sensitivity of the small blade antenna response to different ground conditions (wet vs. dry) and to a ground screen being placed beneath the antenna. The metrics of interest are total antenna loss (due mismatch and ground losses) for a given ground condition (related to signal to noise) and the change in total antenna loss between the extremes in ground conditions (related to variation in signal to noise over time.) Figure 2 summarizes the simulation results.

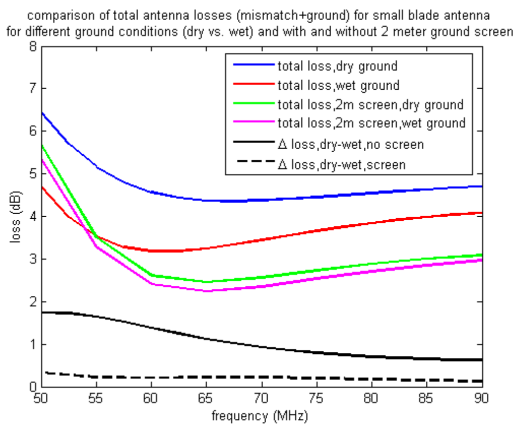

Figure 2: LWDA Ground Screen Simulation Results

The blue and red traces are the total losses of the small blade (with no screen) over dry and wet ground, respectively. As expected, the total loss is higher (signal is lower) for dry ground (more absorption by the ground), however the difference between grounds is not as great as may be expected since the matching improves as the ground dries out. The solid black trace is the difference between dry and wet grounds. The difference between wet and dry conditions between 60 to 80 MHz varies between 1.3 dB to 0.8 dB, which is not too high.

Next, a 2 meter square ground screen, placed very close to the ground, beneath the small blade was modeled. This screen size is a bit bigger than the footprint of the small blade. I then re−ran the simulations with wet and dry grounds. The resulting total antenna losses for dry and wet grounds, respectively, with the ground screen present are given by the green and magenta traces. Particularly for the dry ground case, the antenna losses have been reduced (i.e. signal levels increased) significantly by adding the ground screen; the improvement between 60 to 80 MHz is between 1.9 dB and 1.7 dB. The difference between wet and dry grounds with the ground screen present is given by the dashed black line. Clearly the variation in losses (or signal level) due to different ground conditions has been reduced noticeably to between 0.2 dB and 0.1 dB between 60 to 80 MHz. Preliminary simulations were run assuming that the ground screen was a solid metal sheet. A subsequent simulation was conducted assuming a real wire screen with a 4" square cell size and a wire diameter of 1.6 mm; this is actually slightly less dense that the screen that the NRL folks used in the big blade ground screen measurements a month ago. Although it is not shown in the plot, the total loss given with the real wire screen was nearly identical to a solid metal screen (delta less than 0.1 dB) down to 50 MHz.

In summary, it appears from these simulations that a significant improvement in small blade performance in terms of both signal level and signal level variation due to changing ground conditions can be realized with a reasonable size ground screen (> 2 meters) using a screen material similar to that detailed in NRL's big blade ground screen report. It should be noted noted that this improvement is confined to higher frequencies; in the plot, the performance of the antenna with a ground screen starts to degrade below 60 MHz. A larger ground screen size is required to improve performance at lower frequencies. While this is not necessarily important for LWDA (we can only measured down to ~ 55 MHz anyway), it will necessary to consider the appropriate ground size for LWA antennas in order to achieve good performance over the entire operating band.

Individual Antenna Total Power Measurements

Although we originally planned to take power measurements over a frequency range of 60−88MHz before and after the ground screen installation, for a variety of reasons it was decided to use the normal LWDA imaging mode, which collects data only from 73.0−74.6 MHz. It is hoped that future measurements will study the ground screen improvement over the wider 60−88 MHz band. Figure 3 shows received power at each of the antennas numbered 1−5 on the day of installation plotted against UTC time in hours. By subtracting 6 hours from the UTC time plotted, the local Mountain Daylight Time can be obtained.

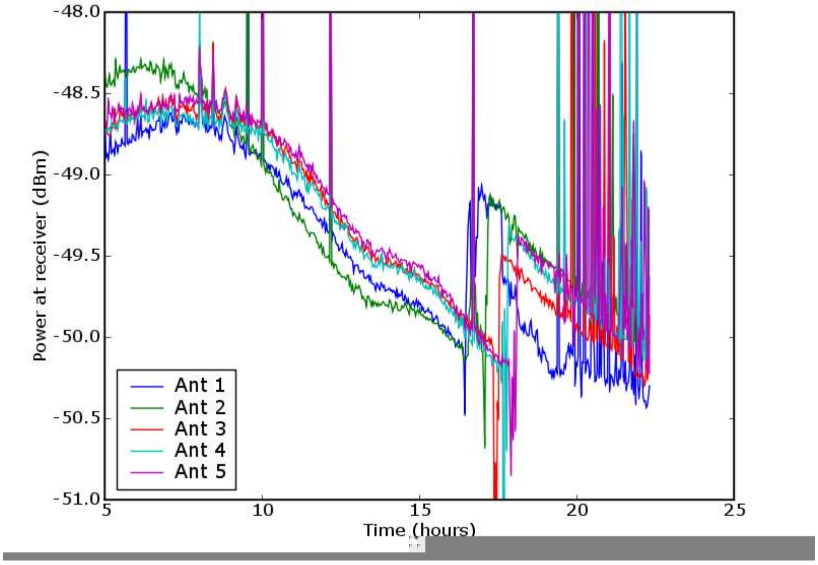

Figure 3: Power from antennas 1−5 of LWDA on the day of installation

A number of important features are visible in figure 3 including:

1. the diurnal variation as the galactic plane transits and begins to set overnight,
2. the sudden increases in power related to ground screen installation beginning with antenna 1 at about

10:30am local time (16.5 hours UTC) or so, and then antennas 2−5 follow in succession. At first glance, the improvement in signal level due to the ground screen appears to be between 0.5−1 dB.
3. what appears to be the effect of distant lightning during the afternoon hours starting about 2pm local time (20 hours UTC).

Also apparent in figure 3 is an unexplained dip in power from antenna 1 a few hours after installation, which seems to be associated with having large rolls of wire sitting next to some of the antennas during the installation process. In order to get a better measure of the improvement by excluding temporary effects during installation, the day of installation was masked out of the data set under consideration, and a scatter plot showing received antenna power against local sidereal time is contained in figure 4.

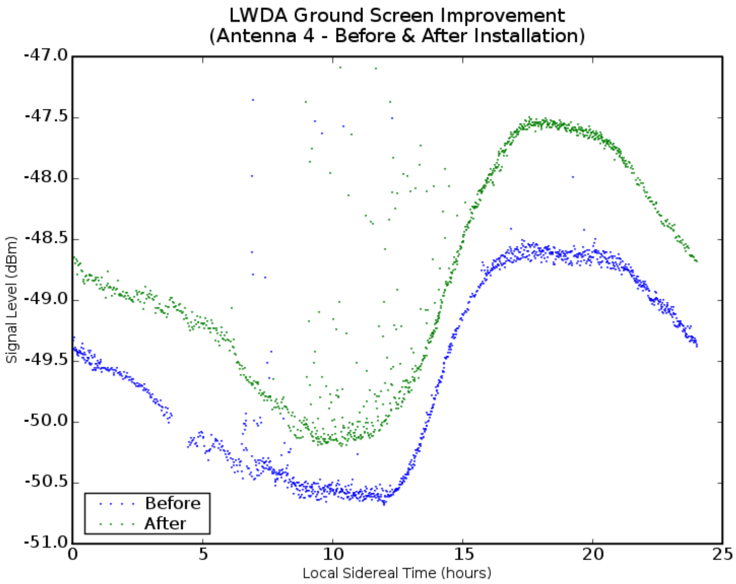

Figure 4: Antenna 4 power at receiver before and after ground screen installation

After writing a simple iterative RFI filtering algorithm, I was able to create a plot showing the improvement in signal strength as a function of local sidereal time shown in figure 5.

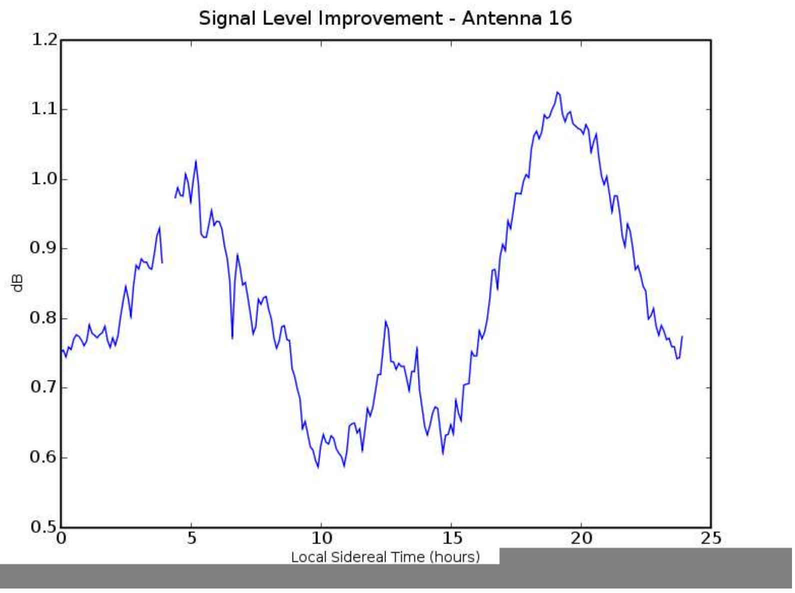

Figure 5: Improvement in received power at antenna 16

A few characteristics of figure 5 are notable, including:

1. The signal level improvement on antenna 16 seems to be range from approximately 0.5−1.1dB depending on local sidreal time
2. Two peaks are apparent, separated by approximately twelve hours.
3. The signal improvement does not consistently scale proportionally with actual signal level, which is consistent with the LWDA being sky noise dominated. That is, the signal improvement does not vary as would be expected if the LWDA were not sky noise dominated.

In order to make sense of the shape of the improvement curve, it is helpful to look at the distribution of the power in the sky at several Local Sidereal Times corresponding to inflection points in the graph above. Shown in figure 6 are the images of the distribution of power in the sky as simulated from the Haslam 408 MHz skymap. The color ranges from blue to red which correspond to lowest and highest power in the sky, respectively. The color scale is not shared between images.

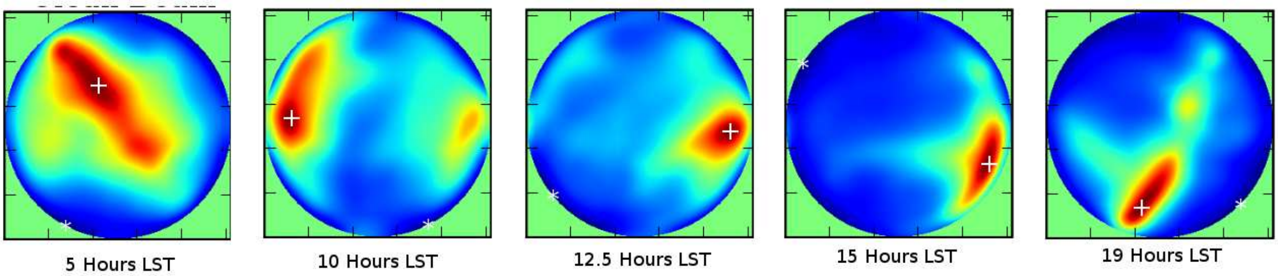

Figure 6: Spatial distribution of power at the times corresponding to inflection points of the signal level improvement for antenna 16

The maxima in the graph at 5 and 19 hours LST correspond with times that the power in the sky was mostly concentrated high above the horizon, with the minima at 10 and 15 hours LST associated with times that most power in the sky was low to the horizon. This is evidence that not only did the ground screen reduce the direction invariant ground loss term, but it also changed the antenna pattern, apparently by making it more directional. The inflection at approximately 12.5 hours seems to be related to the setting of the galactic ante−center in the west and the rising of the galactic center in the east. Potential future work could involve simulating the drift scans with antenna patterns derived with and without the ground screen to obtain a qualitative measure of how accurately the simulation tools model the effects of the ground screen on the antenna pattern.

For completeness, the derived signal level improvement is shown for all 16 antennas in figure 7 as a function of local sidereal time.

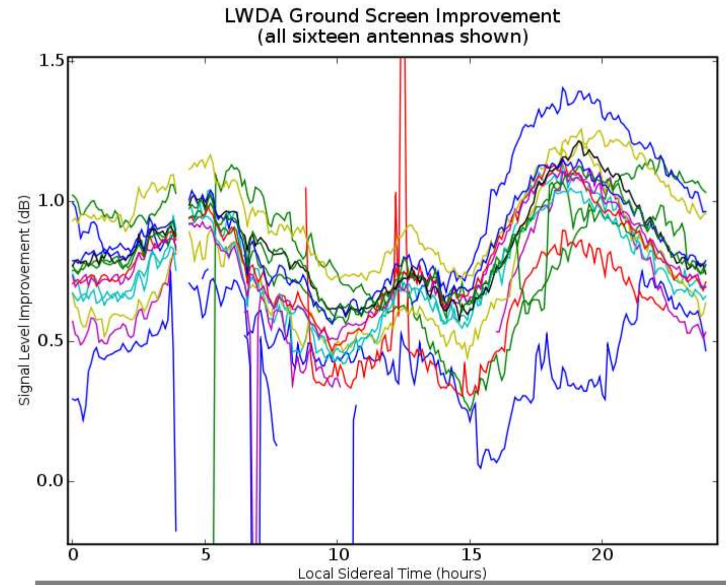

Figure 7: Signal level improvements for all 16 LWDA antennas

Figure 7 shows a signal level improvement ranging from approximately 0.5−1.6 dB depending on the antenna and local sidereal time.

Two element interferometer measurements

In addition to total power measurement from each antenna, the outlier dipole installed in May 2007 was used in conjunction with the LWDA phased to track CasA in a two−element interferometry mode. Figure 8 shows the amplitude of the detected fringes as a function of local sidereal time before and after the ground screen installation. The graph shows approximately 1.4 dB of improvement in signal strength due to the addition of the ground screens beneath LWDA.

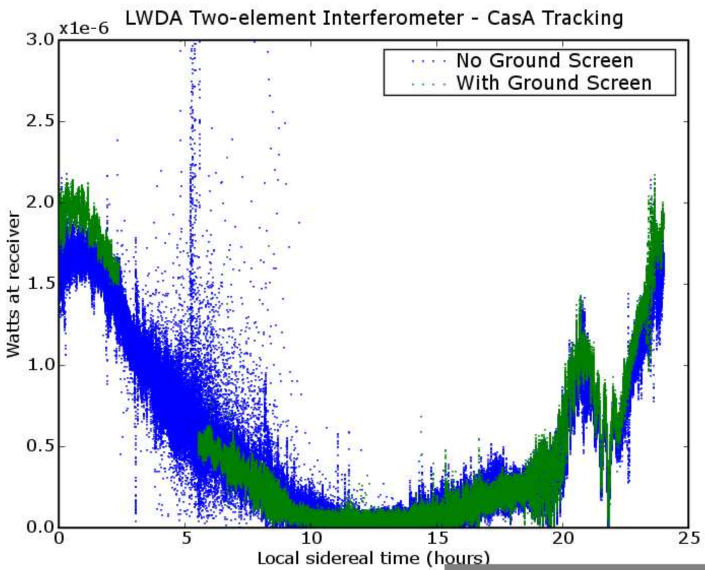

Figure 8: Power of received fringes from correlating the LWDA phased at CasA and the outlier dipole

The "after" trace on the plot above is cut short because of a power outage at the LWDA site from approximately 11:06am to 2:46pm MDT on July 3, 2007. Additional data was collected after the power outage and work on visibility data already collected in this mode is ongoing, and will hopefully reveal any detectable influence on the stability of the phase center of LWDA.

Conclusion

On June 28, 2007 small ground screens were installed under each of the sixteen Long Wavelength Demonstrator Array antennas. Prior to installation, simulations were performed that predict the improvement in signal level at the dipoles to vary between approximately 1.1 and 1.9 dB depending on both frequency and the moisture content of the soil. Total power measurements were taken before, during and after installation of the ground screens and show a total power increase ranging from 0.5−1.6 dB dependent on both the antenna and local sidereal time. The variation in of signal improvement as a function of local sidereal time is shown to correlate with the spatial distribution of power in the sky, hinting that not only did the ground−loss term decrease, but the LWDA antenna patterns have become more directional. Operating LWDA in phased array mode tracking CasA and correlating against the outlier dipole installed approximately 250m to the east of the LWDA showed an aggregate improvement in signal level of up to 1.4 dB, with the most improvement at transit and less at lower elevation angles. Overall, depending on the metric used the new LWDA ground screen appears to have improved signal levels by 0.5−1.6 dB, which is slightly lower than, but still consistent with that predicted by simulation (1.1−1.9 dB).