Holographically Directed Adjustments of the VLA/VLBA Antennas

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Abstract Holographic methods have been developed to assist the optimization of the VLA/VLBA antennas by measuring subreflector offset and primary reflector defects. Antenna #4 and the VLBA antenna at Pie Town were chosen to test the holography on. The recommended adjustments to the VLA and VLBA subreflectors and VLA primary reflector have provided good results. It should be straightforward to continue adjusting antennas.

Introduction

The optics and reflector surfaces of the Very Large Array (VLA) and Very Large Baseline Array (VLBA) were originally installed and aligned with optical instruments. A technique called *holography* allows us to refine the alignment and improve the performance of the antennas[1]. By scanning an antenna through a raster around a point source, and using another antenna pointing at the same source as a reference, we obtain information about the phase and amplitude of the reflected signal off areas of the dish. Holography provides information that can be used to adjust the focus, subreflector alignment, and main reflector panels (primary surface).

Using two holography data sets, most of the VLA antennas were measured for subreflector offsets and panel offsets. Antenna #4 had a bad subreflector offset (16mm, about 5/8"), as well as a bad primary reflector surface (.75mm RMS, about 0.030"). It was chosen to be the antenna subject to the first tests of holographic methods. The VLBA antenna at Pie Town was selected for testing because of its proximity to the VLA.

The first step was to correct the subreflector offsets, then perform holography again to gauge the effectiveness of the adjustments. Then, if necessary, a second adjustment could be done to "fine tune" the antenna. On the VLA, this process was then used for the primary reflector.

VLA Adjustments

Moving the Subreflector

We wanted to find out why antenna #4's subreflector was so far from the optimal position indicated by holography, so we decided to mount a *theodolite* and check the alignment. A theodolite is an optical instrument that measures straightness, flatness, and squareness. By aligning the theodolite with respect to antenna #4's dish, the apparent position and angle of the subreflector is determined. Comparing this to what the holography indicates, we can attempt to determine if the subreflector was installed improperly or has moved.

On June 17th, 1993 the 327MHz feed was removed from antenna #4 and the theodolite mirror installed. We attempted to *planize* the theodolite, or align it with the axis of the dish. However, antenna #4 seemed to have two separate planes. Its four planizing points (located within view of the theodolite) did not form a plane, but instead formed a different plane with each set of three points. It turns out that the four points are not necessarily in a plane, but describe one[2]. This measurement indicated that the subreflector was too far west by approximately 15/64" (about .234" or 5.95mm).

On the next day, the 18th, the subreflector was moved. This was straightforward because the subreflector needed to be moved 16mm (about 5/8", 0.0629") east, parallel to the slots on the focus rotational mount (FRM)[3]. Dial indicators with magnetic bases provided measurement, and long clamps provided movement.

Results of Moving the Subreflector

A quick and easy test of subreflector alignment is a scan through azimuth and elevation of a strong point source and looking at the *sidelobe* pattern. If the two sidelobes on either side of the main beam are of approximately equal amplitude, then the subreflector is fairly well aligned. **Figure 1** shows the sidelobe pattern for antenna #4 before the subreflector was moved. The sidelobes have approximately 6.9 dB (121%) of difference.

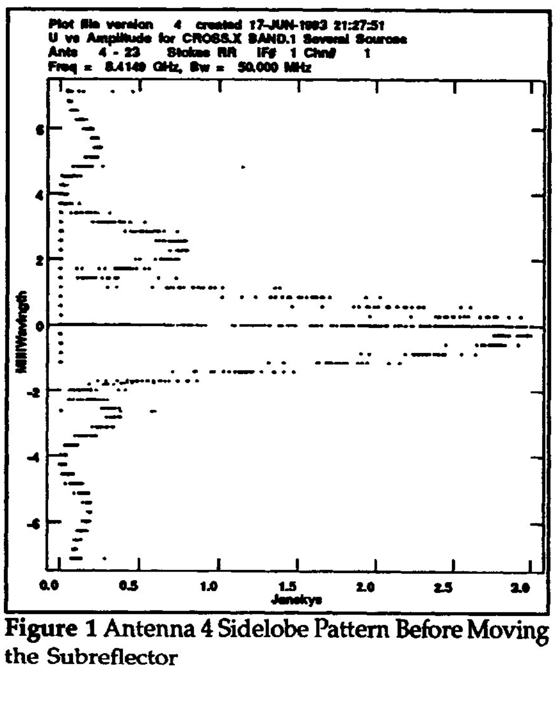

Figure 1 Antenna 4 Sidelobe Pattern Before Moving the Subreflector

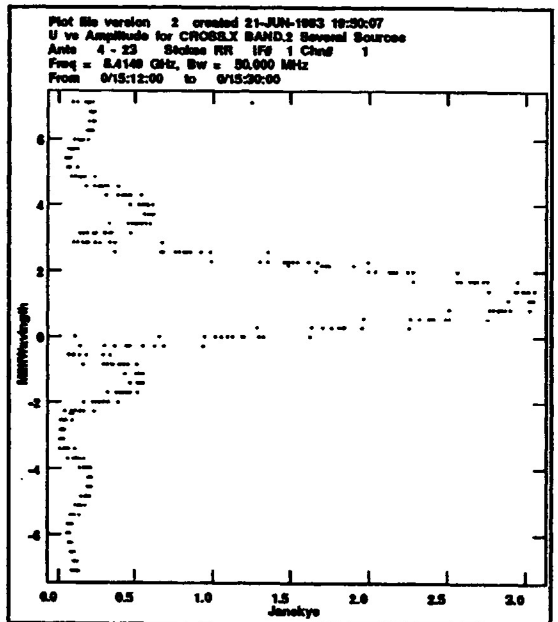

Figure 2 Antenna 4 Sidelobe Pattern After Moving the Subreflector

Figure 2 shows the result after moving the subreflector. The sidelobes are now only about 0.7 dB (8%) apart, which indicates that the subreflector is now much closer to the correct position.

Adjusting the Main Reflector Panels

The main reflector consists of 172 panels in 6 rings. Each panel is adjustable at each of its four corners with two nuts.

Once the subreflector was moved, the holography was repeated to get a good set of main reflector adjustments. M. Kesteven was able to provide us with a list of individual panel adjustments. The list gave a numeric value in thousandths of an inch for moving each corner of each panel.

The Test Run

The first round of adjustments was designed to gauge the effectiveness of the holography. Antenna #4 had large "landmark" errors (see **Figure 3**) on its outer edge of panels. The first adjustments were done on rings 5 and 6 (the two outermost rings), panels 4 to 7, 23 to 26, and 35 to 40 (the panels are numbered starting at the top (North) and incrementing clockwise around the antenna). Corners of panels with an offset of more than 1.0mm (about 0.040") were adjusted, with a total of 53 corners to be adjusted.

A *gauge micrometer*, which is a device that measures small distances (dial indicator), is used to measure the distance the panel has been moved. The gauge mounts to a steel plate with a magnetic gauge base. The steel plate was given a lip to fit in the gaps between the panels for stability.

The method we used was simple: one person stands on top of the dish with the gauge, shouting down the current reading while the other adjusts the panel from beneath[4]. Ramon Gutierrez and I completed the adjustments on the 8th of July, and the antenna was put through a holography run on the 9th.

Results of the Test Run

Figure 3 shows the dish as holography saw it before the first round of panel adjustments. The top of the picture is the up leg (North leg), and the picture is oriented so that one is looking into the dish from the FRM. Thus, the right hand side is the "east" side. One can see the quadrapod as "shadows" on the image in the four compass directions.

One can see the large surface errors on the northeast, southwest, and north-northwest edges. On **Figure 4**, holography after the adjustments, the errors are much smaller. This encouraged us to complete the panel adjustments.

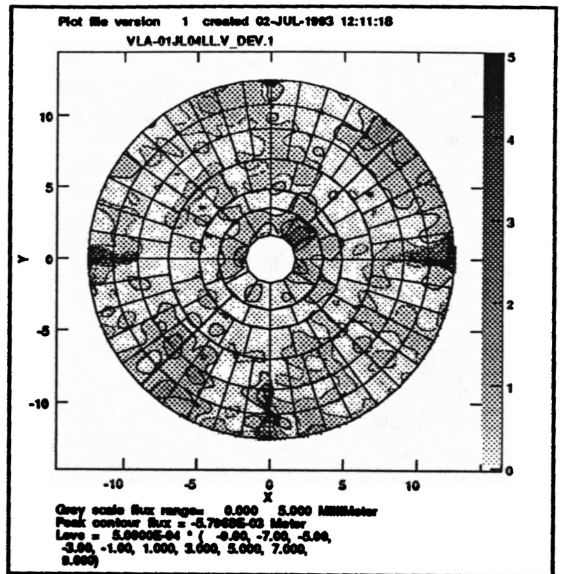

Figure 3 Antenna Four Surface Before Panel Adjustments

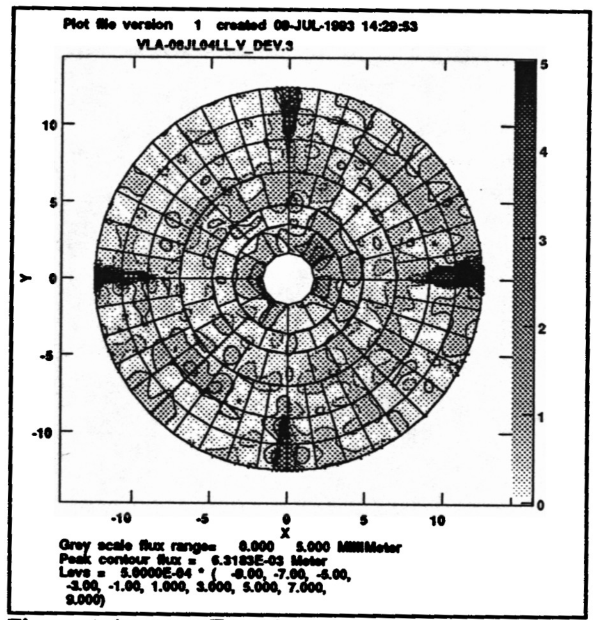

Figure 4 Antenna Four Surface After First Round of Adjustments

Resetting the Primary Surface

After extracting a new set of

adjustments from the latest holography run, we again attacked antenna #4 with wrenches and gauge. This time, we adjusted all panel corners with errors 0.020" or greater (about 0.5mm), as recommended by M. Kesteven (a total of 273 adjustments). The panel edges lying in the quadrapod "shadow" were not adjusted. This took four days in late July and early August to complete.

Results of Resetting the Primary Surface

A good holography run was done on the 24th of August. The results are shown in **Figure 5** (Please note that this image is backwards and upside down). The RMS surface error has been reduced to less than 0.5mm, and the gain has improved by about 2.5 dB[5].

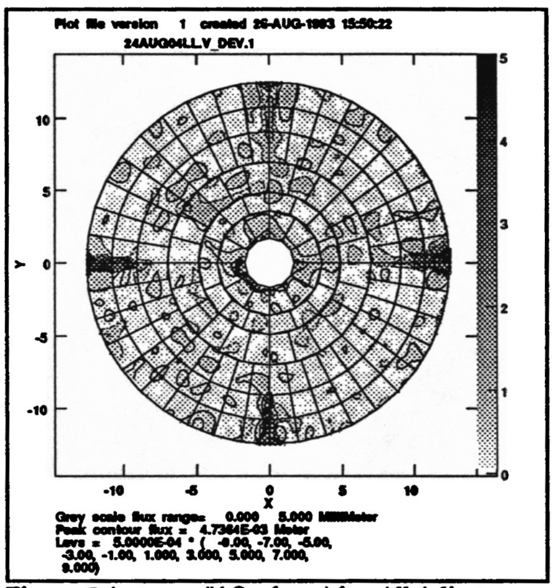

Figure 5 Antenna #4 Surface After All Adjustments (8/26)

Time

Most of the adjustments, rings 1 through 4 and the inner edge of ring 5, can be done with two people, and took 11 hours. The outer rings must be done with a cherry picker, requires three people, and took an additional 8 hours. Adjusting all the bad panels on antenna #4 took 19 hrs, with an additional 1.5 hours per day of setup and takedown time. Assuming ten-hour days at the site:

10hr day
- 2hr breaks, transportation
- 1.5 hr setup, takedown
= 6.5 hr/day for adjusting.

19 hr/antenna adjusting
/ 6.5 hr/day
= 3 days/antenna.

This is assuming good weather (thunderstorms provide a severe hazard on the dish), access to the cherry picker on demand, and prepared holographically derived adjustments. A safer estimate would be 3.5 days, plus time for the holography. The holography can be done many days in advance, and provide adjustments for more than one antenna.

The antenna being optimized is not disabled for observing between adjustment days. It can be used anytime the work team is not adjusting.

There is nothing preventing two or more teams of two people to work simultaneously, which would reduce the time spent *adjusting* proportionately, but the overhead would remain the same. The time spent on a dish would be two to three days instead of three to four days.

VLBA Adjustments

Moving the Subreflector

A theodolite was set up at Pie Town to ensure that the subreflector axis was parallel to the axis of the antenna, and to see if the subreflector offset could be seen with the theodolite.

The subreflector at Pie Town was a little trickier to adjust than the Antenna #4 FRM, it had to be moved down (south), which is not in the direction of the slots. The method we used was to split the movement into its component vectors parallel to the FRM slots.

With gauge micrometers set up on each leg of the FRM, we first moved the top of the FRM along one slot, then the other with long clamps. Then we moved the bottom with the turnbuckles.

Results

The theodolite showed that the axis of the subreflector was parallel to the axis of the antenna, but the planizing points were not small enough to measure the offset accurately. After moving the subreflector, the Pie Town antenna enjoyed a dramatic improvement in gain, but the gain peaked at a high elevation. Ideally, the gain should peak at 45° elevation to ensure good performance at all elevations. A second subreflector move correcting this peak.

Conclusions

Attempting to optimize antenna #4 using holography has been encouraging. It has gone from being the worst antenna to being among the best. A list of subreflector adjustments to be made to the rest of the VLA antennas is available[6]. The process of resetting all the VLA/VLBA antennas with poor alignment should be straightforward.

Notes

1. M. Kesteven. VLA Test Memorandum No. 169, VLA Holography, May 1993. Mike also provided all the graphs for this report.

2. Here's how: the plane of the theodolite is lined up with two points 180° apart. Then the remaining two planizing points are brought equidistant from this plane. The result is the plane used to put the subreflector up.

3. One of the strange aspects of the FRM placement on antenna four was that there were many shims under the east leg of the quadrapod, and the FRM was placed as far as possible in the wrong direction (at the end of the slots on the mount).

4. This method was suggested by Mike Kesteven as the one used in Australia.

5. M. Kesteven. VLA Test Memo No. 173, Antenna #4 Upgrade, September 1993. Page 8.

6. M. Kesteven. VLA Test Memorandum No. 171, VLA Antennas as a Function of Elevation, August 1993. The scale factor on the subreflector offsets is not completely certain as of this date.