HOLOGRAPHIC SURFACE QUALITY MEASUREMENTS OF THE SUBMILLIMETER ARRAY ANTENNAS

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ABSTRACT

The surface smoothness specification for the 6-m diameter antennas of the Submillimeter Array (SMA) is 12 μm, due to its short operating wavelengths down to 300 μm. We describe near-field holographic measurements at 232.4 GHz to map and set the surface to achieve this goal. The surfaces of 4 antennas have been adjusted to better than 20 μm rms so far. The panels on one of the antennas have been set to reach a smoothness of 13 μm rms. Long term monitoring tests show a repeatability of 11 μm rms over 7 months, during which the antenna was transported between pads. The stability of the surface indicates that it will be possible to efficiently operate the SMA, unaffected by Array reconfigurations over long periods.

INTRODUCTION

The Submillimeter Array which recently became partially operational on Mauna Kea is a reconfigurable array of 8 antennas, each of 6-m diameter (Figure 1) [1]. It will carry out synthesis imaging of celestial objects over the wavelength range $\sim 300 - 1500$ μm. For efficient short wavelength operation, it is necessary that the surfaces of the antennas be measured and set to a high accuracy. The SMA specifications require a surface accuracy of 12 μm rms. In this presentation we describe our approach to achieving this goal and the results.

Figure 1: A view of the SMA on Mauna Kea. The Array will have 8 antennas when completed.

STRATEGY

We use a combination of terrestrial and celestial holographic measurements to study the antenna surface. Terrestrial holography using a ground-based signal source can provide high signal to noise ratio. This is our primary method of measuring the figure of the antennas at a resolution of $\sim$ 10 cm across the surface of the dish, at a fixed elevation. The surface error maps generated are used to study and correct panel-panel errors and panel flexing. Celestial holography with coarser resolution, using planets as signal sources, allows us to study gravitational deformation of the dishes with elevation.

MEASUREMENT SYSTEM

We have set up two low-power ($\sim$1 nW) signal sources that emit phase-locked tones at 232.4 GHz and 682.5 GHz for holographic measurements and other general tests of the Array (Figure 2). These are mounted on the Subaru Telescope building, at a distance of $\sim$ 200-m from the central ring region of the Array, in the near-field for the SMA antennas and at an elevation of $\sim$ 19 degrees (Figure 3a). The holography system uses the standard SMA optics, receivers and IF

Figure 2: Test signal sources emitting phase-locked tones at 232.4 & 682.5 GHz, mounted on the cat-walk of the Subaru Telescope.

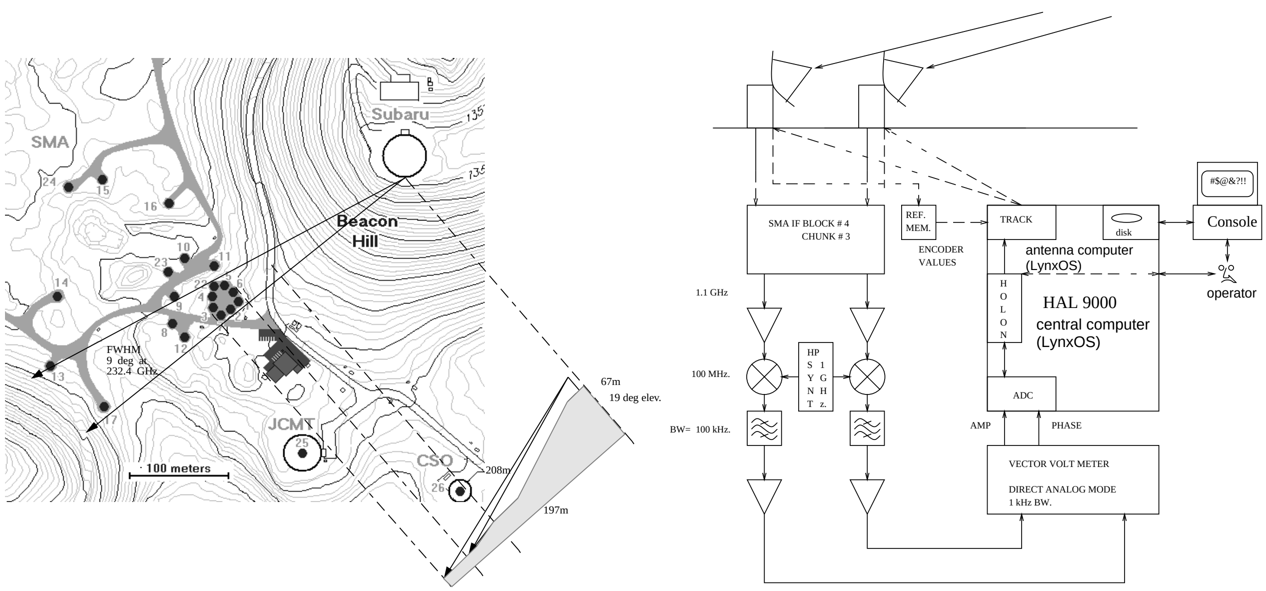

Figure 3: (a) The geometry for SMA near-field holography (b) The holography system block diagram.

electronics. Currently, a vector volt meter is used as the back-end to measure the complex beam pattern of the antenna under test. A block diagram of this system is shown in Figure 3b. A second antenna of the Array provides the phase reference. We will eventually switch over to using the Array correlator as the back-end. The measurements are made on-

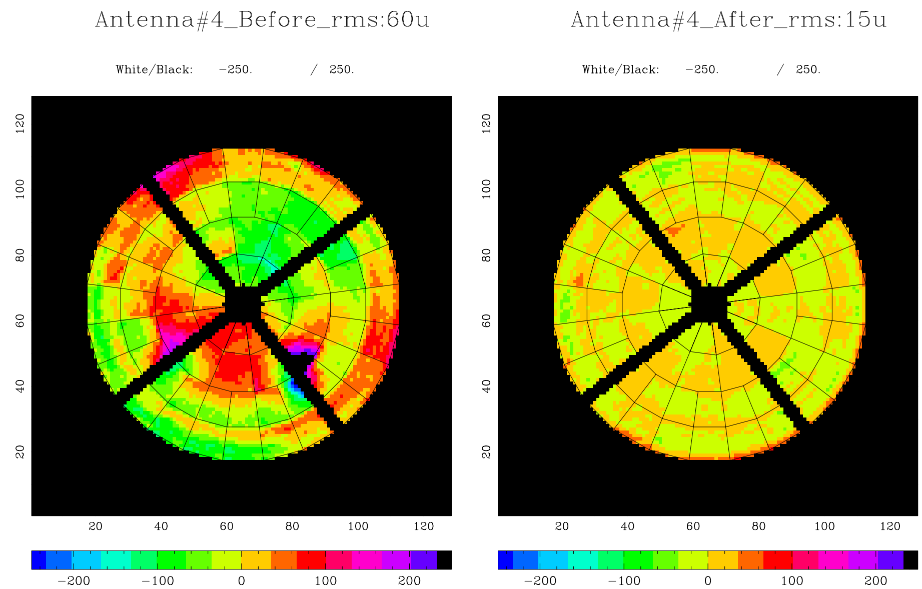

Figure 4: Left panel shows the surface error map when the antenna was first deployed, with an rms of ~ 60 μm. After 3 rounds of adjustment it was improved to 15 μm as shown on the right panel.

the-fly, typically mapping a 96×96 raster with an elevation spacing of $33''$ at 232.4 GHz, with the subreflector refocussed for the near-field.

The data is re-sampled off-line onto a regular grid, Fourier inverted and corrected for the near-field phase profile to produce the aperture phase distribution. After fitting DC, gradient and defocus errors, the phase residuals are converted to surface deviations which are used to adjust the panels. Four maps, made with the subreflector positioned an eighth of a wavelength apart, are averaged to overcome the effects of multiple reflections. A correction for the diffraction due to the finite-sized subreflector is also applied. A complete set of measurements takes about 2 hours.

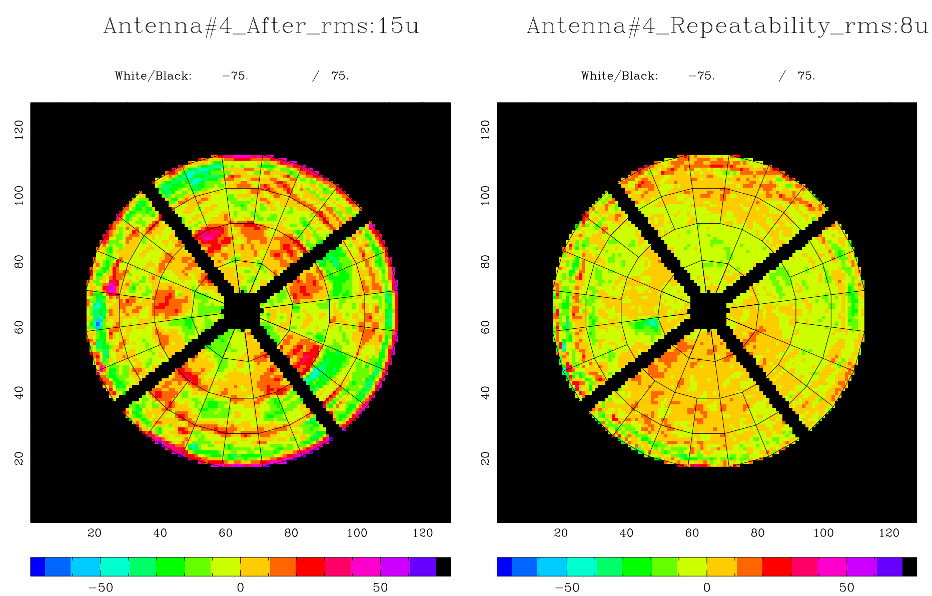

Figure 5: Short term repeatability for Ant 4. Left panel shows the surface error map and the right panel shows the difference of two maps taken 1 month apart, with a repeatability rms of 8 μm

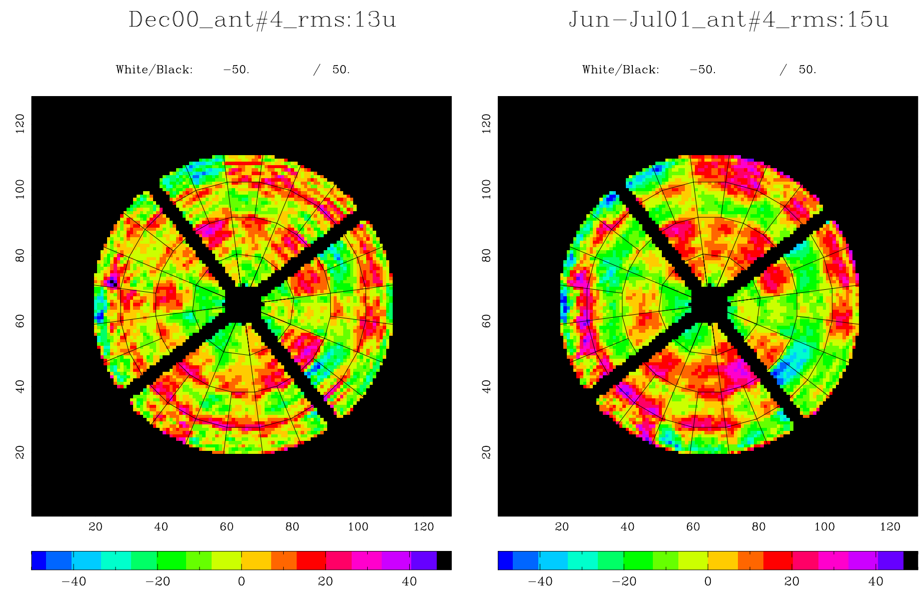

Figure 6: Long term surface stability for Ant 4. The two surface error maps were made 7 months apart. The antenna was moved from one pad to another during this interval. The average surface rms over this period is 13 μm and the end to end repeatability is 11 μm.

RESULTS

So far the surfaces of 4 of the SMA antennas on Mauna Kea have been set to better than $\sim$ 20 μm rms accuracy. The surface of one antenna (No. 4) has been set to 13 μm rms and is under long-term monitoring tests. Typically 3 rounds of adjustments are needed to achieve $\sim$ 15 μm rms starting from $\sim$ 60 μm (Figure 4). The short-term repeatability of the measurements is 8 μm rms and the repeatability over several months is 11 μm rms (Figure 5, 6). This dish is among the best existing radio reflectors in terms of the ratio of surface smoothness to diameter. During the test period, the antenna was transported from one station to another without ill effect. This implies that array reconfigurations will not affect surface accuracy. The current maps of our best antenna show significant repeatable panel-panel errors suggesting the potential for further improvements. Holography at 682.5 GHz is also being attempted [2], which will further reduce the effects of diffraction due to the subreflector and permit the accurate characterization of the high-frequency systems.

REFERENCES

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