Tolerancing of the Submillimeter Array Optics using Physical Optics Simulations

Paul K. Grimes[1*], Scott N. Paine[1], Ramprasad Rao[2], Tirupati K. Sridharan[1] and Lingzhen Zeng[1]
[1]*Harvard-Smithsonian Center for Astrophysics, Cambridge, MA 02138, USA*
[2]*Institute of Astronomy and Astrophysics, Academia Sinica, Submillimeter Array Observatory, Hilo, HI 96720, USA*
[*]Contact: pgrimes@cfa.harvard.edu

Abstract—The Submillimeter Array (SMA) is an 8 element interferometer on Maunakea, Hawaii, operated by the Smithsonian Astrophysical Observatory and the Academia Sinica Institute of Astronomy and Astrophysics. Each of the 6m antennas houses a single cryostat containing four heterodyne receivers, operating between 180 GHz and 418 GHz. Following recent upgrades to the SMA's correlator system, routine observations with the SMA now use two receivers at the same time with each receiver receiving one of the two linear polarization signals from the sky. Observations may be made either with the two receivers tuned to different frequencies, or with both receivers tuned to the same frequency and either combining the outputs for greater sensitivity or forming the full Stokes parameters for polarimetric observations.

In order to achieve maximum efficiency in observations in any of the observing setups, the receivers must all be co-aligned, so that the peaks of the primary beam patterns from each antenna for each receiver are all pointed at the source being observed. At the same time, each receiver must illuminate the dish correctly, to maximize the aperture efficiency. Each receiver has its own feedhorn and focusing lens in the cryogenic receiver insert, and an ambient temperature optics insert used to couple the local oscillator signal into the sky signal and to transfer the sky signal from the moveable wire grid and mirror that separate the sky signal into the two linear polarizations and direct it to the selected receivers. We would like to quickly measure and adjust the pointing and aperture illumination of each SMA antenna for each receiver to ensure that each receiver and its associated optics is correctly aligned.

We have carried out a set of TICRA GRASP simulations of the SMA beam waveguide optics, in which the positions of the optical elements are varied in order to predict the expected changes in the pointing, beam pattern, and aperture illumination, due to misalignments in the receiver optics. These simulations are used in conjunction with 1- and 2-dimensional holography using a beacon overlooking the SMA site to prescribe adjustments to elements within the receiver optics to maximize the antenna efficiency and beam overlap of the SMA receivers. In this paper we present the physical optics simulation set up within GRASP, the key results of the effects of alignment tolerances of various elements of the SMA beam waveguide on the antenna efficiency and pointing alignment, as well as measurement results from holography that validate the physical optics simulations.