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SUMMARY OF PRELIMINARY TESTS OF THE AST/RO INSTRUMENT

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The Antarctic Submillimeter Telescope and Remote Observatory (AST/RO) instrument was lifted to its Test Site in Boston on 16 January 1993 and prepared for observations with a 230 GHz SIS receiver. This memorandum summarizes the results of tests made during Spring 1993 to demonstrate telescope operation and confirm its specifications: pointing tests on stars, skydip measurements of atmospheric transparency and telescope spillover, beam scans on the sun, and spectroscopic measurements of a celestial spectral line source.

Pointing capability of the AST/RO mount was measured with a coaxially-mounted optical-wavelength refractor. This telescope consists of a 75 mm diameter lens and an Electrim CCD camera mounted in a carbon-fiber tube. Field-of-view of the CCD is 12 arcminutes, and the pixel centers are separated by about 3.8 arcseconds. Observations of stars were used to measure relative short-term tracking stability and to determine parameters of an absolute pointing model. Short-term tracking stability was excellent most of the time, with shake and jitter less than 3 arcseconds. The servo system was able to maintain tracking within an arcminute even when hundred-pound loads were suddenly applied to the telescope structure, in simulation of wind gusts. An intermittent error about 1 arcminute in amplitude was seen at times. We believe this is caused by a digital electronic problem in the elevation encoder; the azimuth encoder showed no such problems and since azimuth and elevation encoders are identical, we are confident that the elevation encoder problem is tractable.

Pointing observations were taken on 3 separate nights for a total of over 150 data points. A preliminary pointing model was applied to the tracking system to account for the observed pointing offsets. This model applies corrections for the tilt of the azimuth axis, the non-orthogonality of the azimuth and elevation axes, and terms proportional to cos(az), cos(2az), and cos(3az) which account for non-circularity and roughness of the azimuth bearing. A total of eight pointing constants were fit for both elevation and azimuth offsets. After the pointing model was applied, the pointing was measured to be better than $1'$ over the entire sky. For the range between 40 to 60 degrees elevation and 90 to 210 degrees azimuth, where most of the pointing data were taken, the pointing is better than about $40''$. This pointing is sufficiently accurate for the 4 arcminute 230 GHz beam. Some high spatial frequency pointing errors are apparent in the data. These are most likely due to rough spots on the azimuth bearing and cannot be fit by simple smooth functions. We intend to remove these with a Fourier analysis of the pointing offsets like the scheme developed for the NRAO Green Bank Telescope.

Skydip measurements were made at 230 GHz with an SIS receiver at the coude focus. Total power measurements for the skydip and for scans of the sun described below were made by interrupting the intermediate frequency cable between the receiver and the AOS spectrometer and inserting a radio-frequency (2 GHz) power meter. Figure 1 shows a reduction of the skydip data. The sky transparency is seen here to be very poor: zenith optical depth exceeds 2. Extrapolation of the skydip curve to zero airmass, while uncertain, indicates low spillover. A more accurate spillover measurement awaits a more transparent sky.

In order to measure the telescope beam pattern, the primary mirror was covered with a carbon-loaded polyethylene sheet 0.003 inch thick and pointed at the sun under computer control. Total power in the IF was measured at various points near the sun's limb. Figure 2 shows total IF power plotted against mapping angle from the nominal center of the sun. The triangular points are an azimuth scan, and the open circles are an elevation scan. The solid curve is the predicted result for a theoretically perfect 3.3 arminute gaussian beam convolved with a uniform disk the size of the sun. The vertical scale of this curve was determined by measured power levels at the center of the sun's disk and at a blank sky point several degrees away. One remarkable result is that the IF power is consistent with blank-sky levels when the beam is positioned only 5 arcminutes beyond the edge of the sun's disk, an indication of high beam quality, high beam efficiency and small error pattern. At the frequency of these measurements, the surface accuracy as determined by measurements in the shop is better than $\lambda/100$, but this beam scan can only show that the accuracy is better than roughly $\lambda/20$.

To demonstrate operation of the acousto-optical spectrometer and data acquisition system, the entire system was connected and the telescope position-switched between Orion A and two reference positions each a degree away. Figure 3 shows the gain and Figure 4 shows the noise temperature of the 2048 channels of the AOS spectrometer, measured using warm and cold loads between the receiver and the telescope. The gain is zero and the noise is large at the edge of the band because the bandwidth of the IF amplifiers in the receiver is smaller than the spectrometer bandwidth. Finally, Figure 5 shows a spectrum of the CO J = 2-1 line in Orion A. The line has approximately the correct amplitude and width. A problem with mode-jumping in the local oscillator phase-lock loop caused the line to appear at two different spectrometer channels. Note that the baselines are of high quality despite the large atmospheric opacity.

These tests demonstrate proper operation of the AST/RO telescope. While some problems remain, there is no doubt that the telescope as constructed meets its design specifications.