# Submillimeter Array Technical Memorandum
## (Early draft, not for general distribution)

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### Preliminary Tests on the Modified Azimuth Bearings

**Summary**

During tests in the summer of 1995 (see SMA Technical Memorandum #93), the azimuthal bearings for the SMA antennas were found to be lower in stiffness than the desired specifications. Five of the bearing units were returned to the manufacturer, Avon Bearing, where the preload in the bearing was increased by inserting larger ball bearings in the race. The modified bearings appear to meet the stiffness specification but may exceed the desired torque. We need to conduct additional testing to be sure that the antenna can maintain the desired track error with the new torque values.

**Test Description**

The antenna azimuth bearings are about 3 meters in diameter and weigh approximately 500 Kg. Testing an unmounted azimuthal bearing is impractical, even at the factory. Thus, two of the modified units were returned to the Haystack Observatory assembly site, where they were mounted into antenna base and alidade #2. Electronic levels were mounted above and below the bearing and a force applied to the elevation axis to mimic the over turning moment of a 14 meter per second wind. The force was applied at the elevation axis, where the main effects from the wind will be felt. As an additional check, a micrometer was mounted between the top and bottom surfaces to measure me deflections produced in the direction of the pull.

In the first test the lower of the two electronic levels was mounted on the bottom of the antenna base, near the opening used for access to the cable hookup while the second level was place on the surfaces provide by the top of the lift points on the mount. The alidade was then rotated into each of its four quadrants, and the moment applied by supporting a 750 pound weight attached to a pulley. While the chosen level positions were convenient and allowed full rotation of me antenna during the tests, the lower location proved unacceptable. The total tilt of the antenna is about 2.5 arc seconds, almost totally due to the flexure of the concrete floor. By differencing the two levels, it was possible to determine the differential tilt between the two sensing points. Each of the four directions was indistinguishable from the other in the character of the measurement. No deflections were detected on the micrometers.

The difference in tilt between the top and bottom levels was 0.9 arc seconds, twice the specification. The result was puzzling, not only that it was twice the specification, but that this size of tilt should have produced readings on the micrometer. The micrometer showed no detectable movement, to an accuracy perhaps half that of the levels. It soon was guessed, and apparently correctly, that the base of the structure was flexing and partially compensating for the tilt of the floor in the lower level. (This flexure is parallel to the ground and will not affect me pointing or phase of the instrument.)

The next morning me test was repeated with one of the levels attached directly to the underside of the bearing and the other just above it. Since the doors of the assembly hall must be opened to perform the test, the resulting drafts and temperature changes somewhat compromised the sensitivity. Nonetheless, it was clear that the differential tilts were significantly less than measured earlier, confirming the theory regarding the base. The data from the second day is shown in figures 1 and 2. While the measurements are noisy, especially in the area when the mount is vibrated by adding and subtracting the weight, we can rule out any differential tilts as large as the specification of 0.35 arc sec. The best behaved transitions, shown in figure 2, suggests a probable result of about 0.25 arc seconds.

As further confiiation of the stiffness, the micrometer dials were then replaced with the Kaman position sensors and the variation in surface separation between the alidade and the base were measured in four different orientations. The Kaman sensors are not as convenient to operate, but provide a resolution of about 0.1 microns when used over a small range. Readings of the mechanical motion varied between 1 .O and 2.5 microns at a radius of 1.15 meters. The variation in readings with the Kaman sensors is greater than the levels, since they will measure local deflections and not the overall mount, but the average is quite compatible with the tilt measurements.

The turning torque of the bearings is specified at 4350 Newton meters or 3200 foot pounds. Measurements were taken by mounting a long lever arm on the alidade and pulling on the end with a fish scale. An observer attempted to record the moment the antenna started to move by observing the scale. A summary of the scale readings is shown in Table 1. While occasionally above the desired value, the torque was expected to get somewhat better as the lubricants work into the seals of the bearing with additional motion.

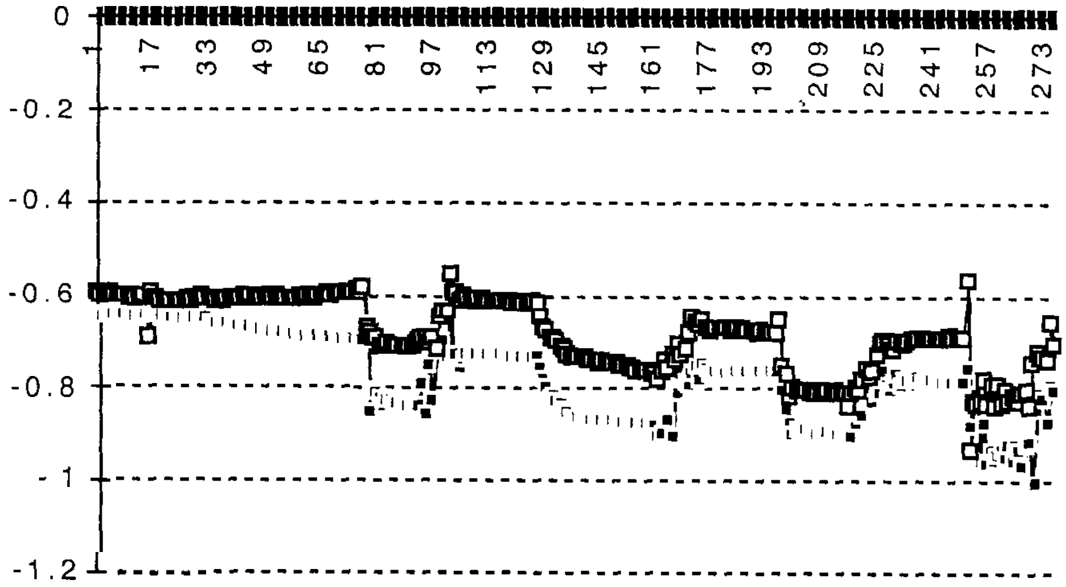


Figure 1: The raw data from the tilts sensors (as expressed in volts) show that both levels are tilting approximately 2.6 arc sec due to flexures in the concrete floor on each of the four load cycles. The drift during the test was due to the very unpleasant temperature environment with the door open.

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**Table 1: Torque Measurements on Modified Bearing #1**
summary of 12 measurements, each trial, evenly spaced in azimuth

| | average | max | min | Stdev | |
|---|---|---|---|---|---|
| lever arm | 11.83 | 11.83 | 11.83 | 11.83 | feet |
| trial 1 | 228.46 | 320 | 180 | 38 | pounds |
| trial 2 | 236.15 | 370 | 180 | 59 | pounds |
| average | 232.31 | 305 | 185 | 42 | pounds |
| average torque | 2748.97 | 3609 | 2189 | 502 | Ft*pounds |

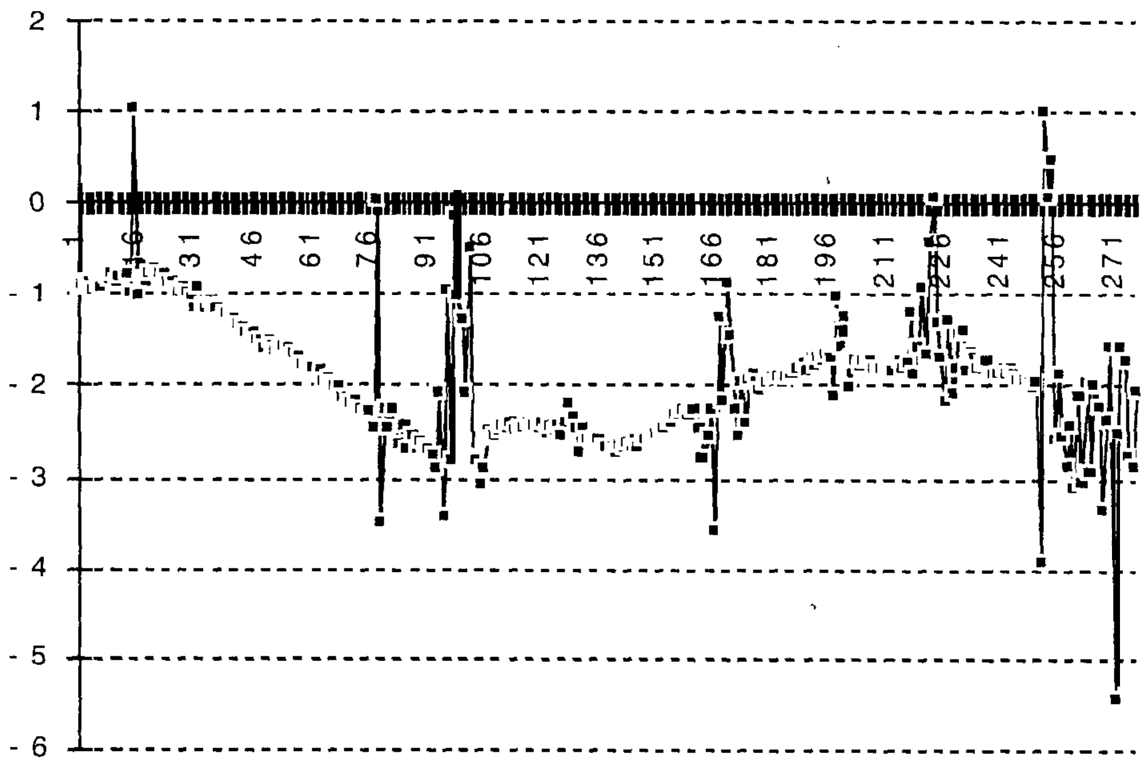


Figure 2: The difference in the two sensors is plotted above, expressed in arc seconds. The transitions at channels 129 and 196 are the best indicators of the differential tilt, and indicate a flexure in the bearing of less than 0.25 arc sec as the mount is loaded and unloaded.

**Bearing #2**

In early January the second bearing was mounted into mount #2 and the tilt tests repeated. The electronic levels were mounted simultaneously with the Kaman sensors at radius of about 1.143 meters. The levels were mounted above and below the bearing as in the previous test. Unlike the previous example, cables were arranged to allow the load to be applied without opening the door of the assembly hall. The latter greatly improved the signal to noise of the measurements.

The electronic level readings are shown in Figures 3 and 4. In the direction of the cabin the levels indicated a deflection slightly over the specification of 0.4 arc seconds while in the direction of the reflector somewhat less. The Kaman sensor consistently gave readings of 3 microns deflection or an implied tilt of about 0.5 arc seconds toward the reflector and only 1-2 microns or 0.2 arc seconds toward the cabin, in the opposite sense of the levels. In the total they indicate that the stiffness is much higher than during the tests of last summer. The variation between the levels and the separation sensors is not necessarily a contradiction, only an indication that we can not tell exactly where the local deflections are occurring in the bearing.


Figure 3: Pull tests on bearing # 2 in the direction of the cabin with the mount pointing toward the neutral point show the deflection of the mount from the vertical above and below the azimuth bearing. Both sets of raw tilt measurements are plotted in arc seconds, as well as the difference between the two. The difference indicates a flexure in the bearing of about 0.5 - 0.6 arc seconds.

The torque tests on bearing #2 were taken in much the same way as with bearing #1 with the exception that no observer was used to record the starting torque of the rotation. Instead the peak torque was recorded by the scale with sliding stop. This tends to overestimate the torque by the amount of addition force used to accelerate the mount. The results are shown on Table 2. These torque measurements are consistently above the desired value, but we do not know by how much they were affected by the manner in which the test was done.

## Conclusion

It would appear that the stiffness of the bearing has been greatly increased by the larger balls with an accompanying increase in required torque. Conclusions as to whether the additional turning friction or the variations in this friction are acceptable will need to await a measurement of the actual tracking error of the mount under servo control.

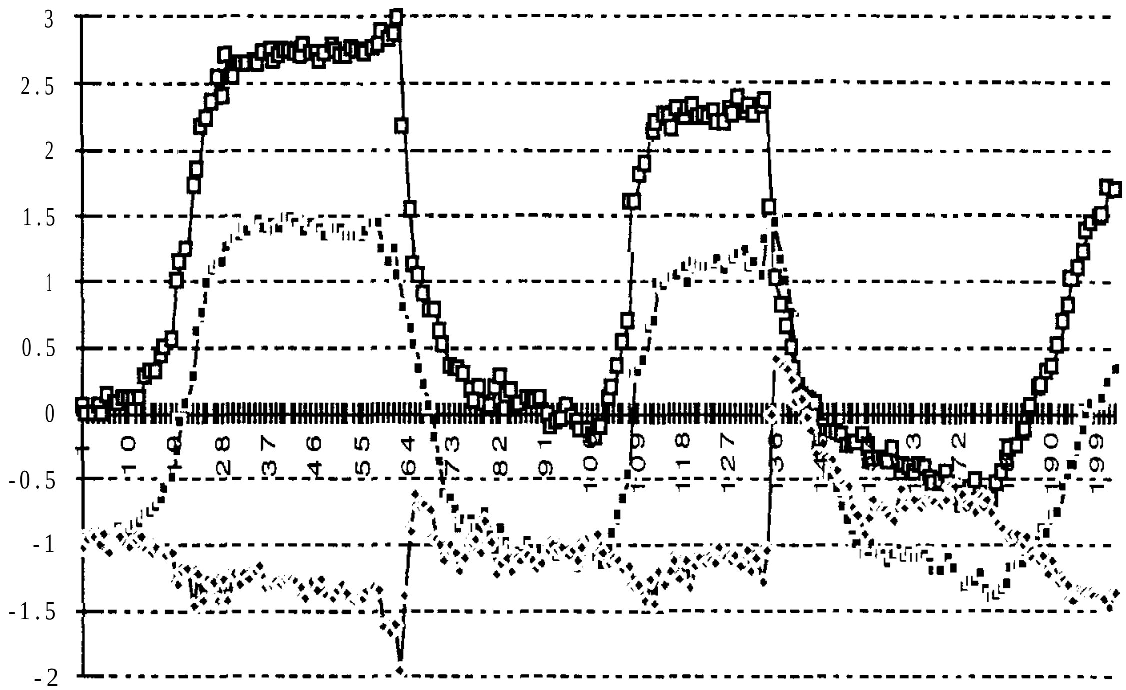


Figure 4: Pull tests in the direction of the reflector with the mount pointing opposite the neutral point, show significantly less deflection in the bearing than toward the cabin. The difference between the loaded and unloaded cases above and below the bearing is shown as the lower of the three plots. As before the total motion of the mount is about 3 arc seconds, presumably mostly from deflections in the concrete floor; however the difference changes by only about 0.2 arc seconds during the load change.

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**Table 2: Torque Measurements on Modified Bearing #1**
summary of 12 measurements, each trial, evenly spaced in azimuth

| | average | max | min | Stdev | |
|---|---|---|---|---|---|
| lever arm | 11.83 | 11.83 | 11.83 | 11.83 | feet |
| trial 1 | 358 | 470 | 260 | 66 | pounds |
| trial 2 | 333 | 420 | 250 | 59 | pounds |
| Trial 3 | 350 | 430 | 290 | 45 | pounds |
| average | 347 | 413 | 277 | 50 | pounds |
| av torque | 4106 | 4891 | 3274 | 592 | ft*pounds |