Alignment of the Atmospheric Visibility Monitoring Telescope

K. Cowles and D. Erickson
Communications Systems Research Section

Alignment of the first Atmospheric Visibility Monitoring telescope has revealed errors in mount design, mount manufacture, software, and electronics. This article discusses error sources and solutions, and realignment results. Alignment requirements for operation are also presented. The telescope now operates with the desired accuracy and repeatability.

I. Introduction

The Atmospheric Visibility Monitoring (AVM) telescope system requires fine alignment and repeatability to accurately move autonomously from one star position to another. The system measures starlight transmission through the atmosphere to provide joint visibility statistics for three sites in the southwestern United States. The sky will be scanned once an hour; the more stars that can be seen in an hour, the better the characterization of the atmosphere. In general, better alignment and repeatability decrease the time used to measure the illumination from each star. Initial alignment attempts revealed obvious problems with the telescope mount design and manufacture, and with the drive electronics. These problems prevented alignment. Specifically, the driver electronics caused the driver motors to run away randomly, declination bearing mounts had no means for adjustment during alignment, the declination wheel was continuously warping due to poor design, and declination and right ascension bearings were contaminated with dirt. Repairs to and replacements of each of these components allowed the mount to be aligned. The accuracy and repeatability of the mount's pointing was characterized.

During alignment, less obvious problems with the mount design and manufacture, and the driver software were revealed. Possible solutions, corrections made, and results are presented in this article.

II. Sources of Inaccuracy

Three problems inhibited accuracy and repeatability of the telescope pointing for the acquisition of stars: slippage during moves, preloading of the right ascension assembly due to the wheel not being concentric with the south-bearing shaft, and an improperly preloaded drive shaft for the declination wheel. Several measurements of error for travels of various distances were made to determine the effect of these problems on the ability to acquire stars.

A. Slippage

Slippage during moves from one star to another was caused by an abrupt start and stop of the frictional drive. In the original software, the stepper motor controllers received instructions to slew to a new position in the form of a direction and a constant speed. The sudden motion from the stopped position to full speed and from full speed to stopped caused the wheels to slip on the drive shaft, introducing errors.

B. Right Ascension Drive Preloading

The right ascension wheel was balanced statically by measuring the torque required to move the wheel with a torque wrench. Magnetic counterweights were attached to the wheel in an attempt to compensate for torque differences. Some errors were not able to be eliminated using counterweights. These errors have been attributed to errors in the right-ascension wheel assembly, which was found not to be concentric with the South Pole bearing shaft. This caused uneven preloading, requiring more torque to turn the wheel at certain points. Figure 1 shows the torque necessary to move the right ascension wheel before it was repaired. The large peaks on the prerepair curve display the preloading effect. This error was also seen in alignment. When moving in right ascension where the wheel corresponded to a peak on the curve, larger positional errors were seen in locating the next star.

C. Declination Wheel Preloading

A static balance of the declination wheel was done separately from the alignment procedures. During the alignment procedures for the declination axis, the telescope appeared to be weighted more heavily to the south. Addition of weights to the north did not appreciably change the errors. Theoretically, if the telescope were heavier to the south, it would step too far south when moving south, and not far enough north when moving north. Changing the weights had little effect, however.

A compression spring preloads the drive shaft of the declination wheel. Decreasing the spring tension decreased the south-going error. If the spring tension was decreased to the point where there was still enough tension to drive the wheel without slippage, the telescope still pulled slightly to the south. By using counterweights and lowering the spring tension, the telescope could be moved between stars located between 20 deg N and 20 deg S with smaller errors. However, these errors were nonrepeatable, differing by up to 1.5 arcmin when traveling from north to south. This range limits the available area of the sky considerably. The problem has been attributed to improper preloading of the declination wheel, as seen in Figs. 2 and 3. Figure 2 shows the configuration of the declination drive. Figure 3 indicates the direction of force from the drive shaft onto the declination wheel. Figure 4 indicates the direction of the force that should be applied for proper preloading. Figure 5 indicates how the drive could be reconfigured to achieve this preloading.

III. Motivation for Improving Alignment

A telecompressor lens system is affixed in front of the camera to increase the field of view from 3.5 × 3.5 arcmin to 10.5 × 10.5 arcmin. A star can be 5.25 arcmin from the center of the viewing field and still be in the field of view of the initial frame, and 15.5 arcmin from center and still be found using a one-loop-square spiral search (assuming overlapping frames). Alignment of the telescope should provide for all stars to be found within 15 arcmin of the initial telescope move.

Better alignment allows more stars to be found on the first frame. If more stars can be found in the first frame, the number of stars that can be observed in an hour will increase. If a star cannot be found, the algorithm assumes a cloud is present, which would give incorrect data in the case of a star being farther than 15 arcmin from the initial telescope move. If the telescope system cannot find three stars in a row, it goes to the home position and reinitializes, a process which again takes time and introduces error in long travels. Improving the alignment of the telescope will result in a larger quantity of more reliable data.

IV. Implementation

A new version of the software ramps the speed of the motors between stopped and full speed, and vice versa, creating less wear on the motors and reducing errors. This should eliminate errors associated with sudden starts and stops in moves, thus improving repeatability in both the declination and right-ascension axes.

The right-ascension wheel assembly for the third telescope was remachined by the manufacturer to repair a damaged surface. While under repair, it was discovered that the south-pole bearing shaft was not concentric with the right-ascension wheel. It was determined that the preloading of the right-ascension wheel on the first telescope was probably caused by a similar problem. The first and second right-ascension wheels were then sent for repair. These wheels were also found not to be concentric. The center of the wheel for the first telescope was off by 3/8 in. Repairs were made to both of the wheels.

The declination motor assembly and motor shaft have been redesigned and rebuilt, as indicated in Figs. 2–5, to provide proper preloading. A photograph of the present configuration is shown in Fig. 6.

V. Results

The curves in Fig. 1 showing conditions following repairs indicate that errors have been reduced by the machining of the right-ascension wheel. Balancing following the machining has resulted in a more even amount of torque necessary to drive the wheel.

Positional errors in moving between several bright stars were recorded after the right-ascension wheel modifications, software ramping modifications, and alignment. Fifty-five percent of the stars were found within the first frame of acquisition. Twenty-seven percent more stars were found with the use of a spiral search. However, 18 percent of the stars were not found because of large errors in the declination axis. Although star acquisition success was not measured in the same manner before these modifications were made, operator knowledge through repeated use of the system indicated that it was acting in a more accurate and repeatable manner.

Positional errors were measured again following modifications to the declination drive. Small and large moves between stars were performed to simulate typical telescope operation. Longer movements did not indicate any increased difficulty in star acquisition. Sixty-nine percent of the stars were found on the first frame, and the remaining 31 percent were found within one spiral search.

VI. Conclusion

Flaws in design and manufacture have caused delays in integration and deployment of the first automated telescope mount system. The flaws were characterized during the initial alignment process. Repairs to the system have been made to eliminate these flaws. Tests were made to confirm the improvements to the system. The telescope now operates with the desired accuracy and repeatability, moving to stars within an error of 15 arcmin. Errors in telescope mount design and system alignment no longer inhibit star acquisition. Therefore, characterization of atmospheric transmission is not expected to include errors associated with equipment design and manufacture.

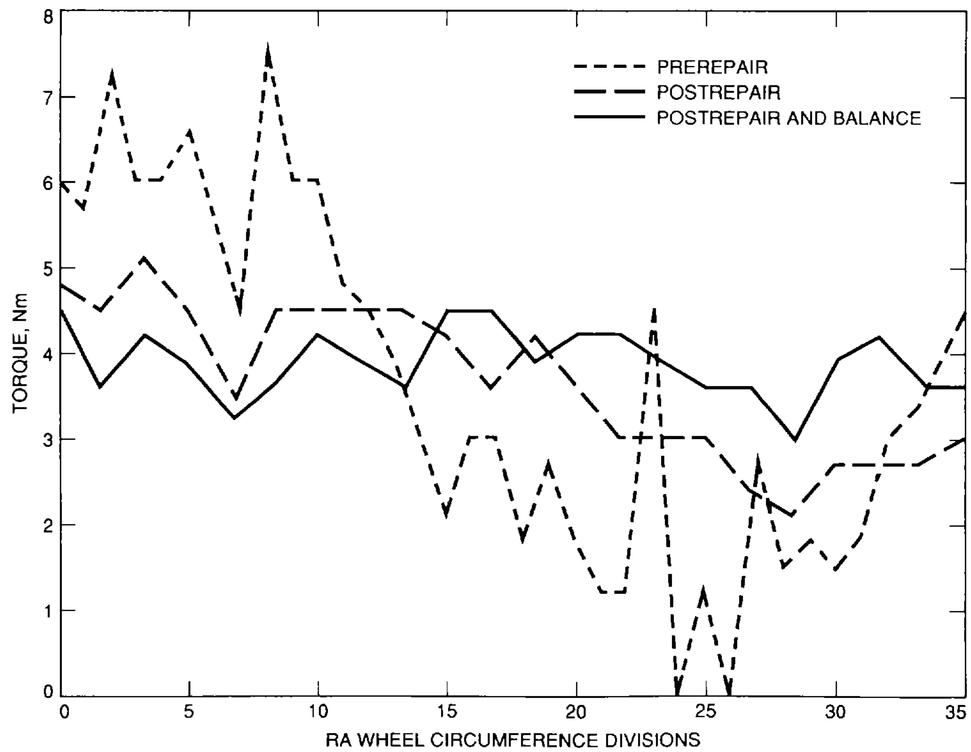

Fig. 1. The torque necessary to move the right-ascension wheel before repair, after repair, and after repair and balancing.

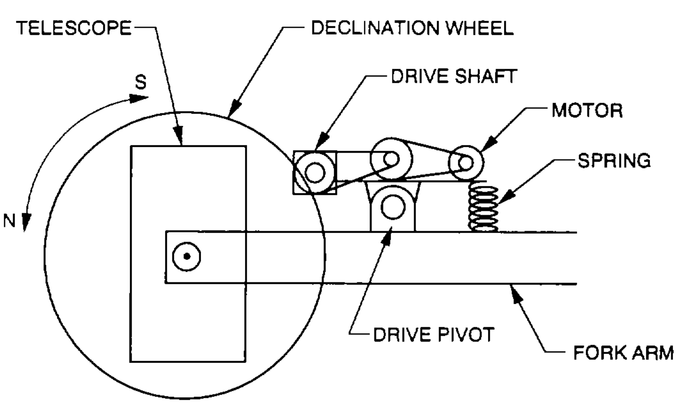

Fig. 2. Declination drive of the manufacturer's design.

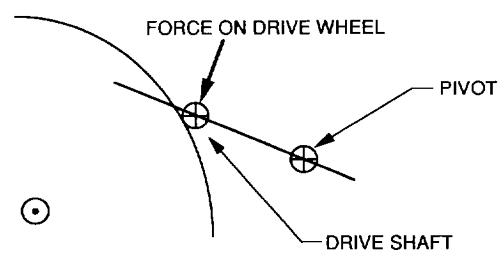

Fig. 3. Directions of force on the declination drive of the manufacturer's design.

Fig. 4. Directions of force of the modified design for improved acquisition accuracy.

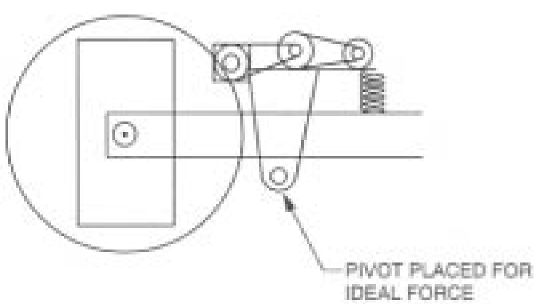

Fig. 5. Declination assembly configuration of the modified design for improved acquisition accuracy.

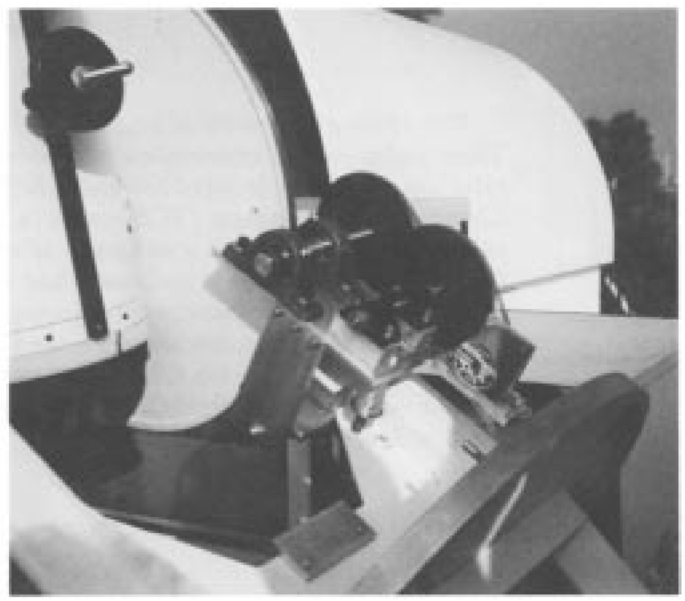

Fig. 6. The present configuration.