VLA TEST MEMORANDUM NO. 160

VLA AND VLBA ANTENNA TEMPERATURE MEASUREMENTS

C. Janes

December 1991

VLA and VLBA Antenna Temperature Measurements

VLA Test Memorandum No. 160

Introduction

Temperature differentials on structural members of antennas can cause the beams to expand and warp, interfering with good pointing. We used an Inframetrics model 525 IR scanning thermographic camera to find "hot spots" and temperature differentials on one VLA antenna and two VLBA antennas. To form an image suitable for display on a video monitor, the camera uses low inertia mirrors to scan the image across a single pixel IR detector. J. T. Williams of SAO/MMTO operated the camera which belongs to the University of Arizona.

VLBA Antennas Measured

We conducted three different measurements on two different antennas: two at Kitt Peak and one at Pie Town. The tests at Kitt Peak were done July 29th, 1991, one about 30 minutes before sundown and one 30 minutes after. Ambient temperature was 18.2°C before sundown and 16.6°C afterward. At Pie Town, the test was done at 10 am December 10th, 1991. Ambient temperature was 5.8°C. In all three cases it was partly cloudy and breezy.

VLA Antenna 6

We conducted measurements at three different times on Antenna 6 at the VLA: one at 10 pm December 10, 1991, one at 6:30 am the following morning, and one at 1 pm that afternoon. The location was pad N12. There was no wind and mostly clear sky for the first two measurements; it was partly cloudy and breezy for the afternoon measurement. The ambient temperature for the night time test was -1°C when we started, and dropped to -4°C by 11:07 pm when we quit. For the morning test, ambient was -3°C, and for the afternoon, 10.5°C to 12°C.

Calibration and Setup

To establish air temperature as a reference point, we aimed the camera at a target made of black felt mounted on cardboard at Pie Town, and at a tree stump at Kitt Peak. Absolute air temperature was recorded from a Fluke meter and probe. Temperature readings in this report are interpolated from reference points using scale marks from the camera video.

To display relative temperatures, the camera outputs a gray scale representation of the scanned scene on a video monitor. A cross cut across the image displays a temperature profile along the cut. In "isotherm" mode, all pixels of equal temperature are displayed as white, so that an isothermal contour is readily visible. A cursor on the temperature scale indicates the relative temperature of the contour.

The camera video with an audio track was recorded on standard VHS VCR cassettes, which have been saved. Figure 1 and 2 provide specifications and an optical diagram for the camera.

2 *VLA and VLBA Antenna Temperature Measurements*

VLBA Measurements

In all cases, the camera showed the feed cone was warm: at Kitt Peak 2°C above the temperature of the dish. The warming appeared symmetrical about the center axis of the dish.

The quadrupod legs that support the subreflector were 0.5°C over ambient at Kitt Peak after being in partly cloudy sunshine all day, but at Pie Town in the morning with little solar warming, the legs were only 0.2°C above dish temperature. At Pie Town, the legs were cooler at the base where they couple to the structure, but other than that, the legs were uniform in temperature from sunny side to shady side, from end to end, and from leg to leg.

The antenna dish itself was uniform in temperature measured to an accuracy of 0.1°C, in all 3 tests. The absolute temperature of the dish tended to be slightly cooler than air, by -0.8°C at Kitt Peak after sundown, and by -1°C at Pie Town.

The hottest spot on the focus rotation mount was 1°C above air. The floor, walls, and roof of the vertex room radiated heat, and a differential of 0.25°C was noted across the base of the room when the dish was viewed from the back.

The elevation axle at Pie Town was warmer in the center by 0.75°C, but the temperature difference curve was symmetrical about the axle center point. The overall temperature of the axle was 2°C cooler than air. The elevation encoder was warmer than the axle, and the elevation drive motors show up as a "hot" spot.

The antenna support structure temperature was uniform; no differentials were noted. The overall temperature followed ambient well, measuring < 1°C above air.

The pedestal room radiates heat in a nonuniform manner, but it is not coupled with the remainder of the structure.

We measured a differential of 0.25°C along one of the horizontal base support beams at Pie Town. That differential does not count the 0.4°C temperature drop measured at the extreme ends where the beam couples with the support legs and adjoining beam. Presumably the thermal mass of the corner joint is greater and takes longer to warm. The azimuth drive motors radiate heat.

At Kitt Peak, the circular concrete pier which supports the antenna wheels was 6°C warmer than air before sundown, cooling to 4.5°C above air after sundown. The pier was only 1°C above air on the south side of the structure at Pie Town.

VLBA Conclusions

The only temperature differentials of consequence were measured in the circular concrete pier which supports the antenna wheels. J. T. Williams notes that CTIO used titanium dioxide paint on concrete around their 4 m telescope to dramatically reduce daytime heating.

That the quadrupod leg temperatures are uniform from leg to leg and from front to back is supported by temperature sensor measurements made on the antenna 6 legs at the VLA. Where the temperature sensors at Pie Town show differentials in the steel structure, the effect may be a result of poor coupling between sensor and structure. The sensor mounting methods used at

Antenna 6 at the VLA provide good coupling; the sensors at Pie Town should be remounted if accurate temperature readings are desired.

VLA Measurements

Some IR camera measurements showed the antenna dish to have a small temperature gradient from the vertex to the edge, amounting to a fraction of a degree C. The gradient appeared to be symmetrical about the center axis. Other measurements seemed to show the entire dish was isothermal, but a fraction of a degree less than ambient. When part of the dish was exposed to the sun, those panels heated up to 1°C over the panels in the shade. At night it was possible to see the outline of the panels, possibly from reflection of the night sky by the panel edges or from increased radiation of the edges to the night sky. The antenna support structure was isothermal at night, +0.5°C over air temperature.

At dawn, the vertex assembly was 2.5°C above ambient on average, with the hottest point 3.5°C above.

Though the subreflector support outer surface was at ambient, the electronics package behind the subreflector radiated noticeably, the hottest point being 9°C above air when measured at night.

Like the VLBA, the quadrupod legs were uniform in temperature from front to back, from end to end, and from leg to leg at -0.3°C below ambient temperature. The legs were slightly warmer than ambient at both ends where they couple to the other parts of the structure.

Since the yoke is insulated, the yoke itself can be quite warm while the outer "skin" is at or below ambient. As proof, the uninsulated bottom of the yoke measured 3.5°C above ambient at night, with a fraction of a degree C differential between yoke ends, while the skin measured to be at ambient. Also, at night holes in the insulation reveal a warm surface underneath. The upper pedestal room glowed like a beacon at night, with a temperature 5°C above ambient. At the top of the yoke arms, the trunion bearings measured 1 to 2°C above ambient. Measuring the gradient from yoke bottom to trunion is confused by encoder housing heating at the top of one of the yoke arms, but the gradient appears to be 4 to 5°C. Since the pedestal room is heated during the winter and the yoke and arms are open to the pedestal room, the vertical temperature gradient through the yoke is most likely caused by heat rising through the structure from the heated room.

The bottom of the yoke measured to be 1.5°C over ambient at dawn, but the ambient temperature by that time had increased by 2°C over the night time measurements. Heating of the yoke does not keep up with ambient during the day; the bottom of the yoke was -2°C from air in the afternoon. The differential between ends was still only a fraction of a degree C.

There is some heat radiation through the insulation of the pedestal room at night.

At night, the elevation encoder housing measured to be 4.5°C above ambient, with the hottest part off the camera scale (> 10°C above ambient). The heating is a result of temperature regulation of the encoder done with air from the vertex room exhausted through the encoder enclosure. In the winter, the heating conducts into the trunion, upper yoke arm, and elevation axle. The encoder housing was also warmer than ambient in the daytime.

The floor of the vertex room was noticeably warm at night in an uneven pattern.

Some structural members that attach to the ends of the elevation axle to support the elevation drive arc were a fraction of a degree C above night time ambient. At night, the elevation axle was warm at the encoder end by 2°C presumably from encoder heating, and was about 1°C above ambient at the opposite end as well. The axle was a fraction of a degree cooler than air at dawn with a gradient from end to end of as much as 0.5°C. In the afternoon, the axle ends were slightly cooler than ambient, most likely a result of the higher thermal mass where the axle joins the support structure. There was a slight temperature gradient across the axle peaking at 0.25°C at the center.

Though cooler than ambient during the day, the counterweights measured to be 3.5°C above ambient at night, uniformly heated to within 0.5°C, apparently the result of that assembly's massiveness. The horizontal base support beams were at thermal equilibrium in all tests within a fraction of a degree C of ambient.

The camera showed that the concrete piers retain daytime heating. Six hours after sunset, the south faces of the west and south piers measured 3.5°C above ambient and at dawn 3°C above.

VLA Conclusions

Absolute temperature sensors show the rise and fall of temperatures from night to day, but the IR camera brings a different perspective: it shows the difference in temperature between ambient and structure. The camera shows that the "delta T" or temperature difference between structure parts and ambient can be large at night, but pass through 0 and become negative during the daytime. For instance, the counterweights are several degrees above ambient at night, but cooler than ambient in the daytime. Yet the absolute temperature of the counterweights goes up and down from day to night just like ambient. Since it is delta T that causes structural deformations, not simply a change in temperature, the camera measures likely deformations more directly.

A notable exception to reduced "delta T" in the daytime are the concrete piers. Measurements with camera and sensors show the piers have high temperature differences both between night and day and between concrete and air. I was unable to demonstrate a relationship between tilt and heated piers in the experiment wherein I insulated the piers (VLA Test Memorandum 156), though the test should be repeated once the effect of temperature differentials in the yoke are reduced. It may be simpler and cheaper to paint the piers with titanium dioxide instead of installing insulation.

Because of the yoke insulation, we were unable to verify the temperature difference of 5°C between yoke faces as measured with temperature sensors (VLA Test Memorandum 156). The camera did clearly "see" a decreasing vertical temperature gradient at night from the pedestal room to the tops of the yoke arms. Given King's calculation that 5°C temperature differential in the yoke will give a 25 arcsecond tilt deviation (VLA Test Memorandum 129), one can easily imagine that the yoke temperature gradient of 5°C is a major contributor to an antenna diurnal average tilt of around 35 arcseconds as measured a year ago (VLA Test Memorandum 156).

5 *VLA and VLBA Antenna Temperature Measurements*

VLA Recommendations:

1. For a test, close off the hatch and cable wrap access between lower and upper pedestal rooms, and repeat measurements of tilt and temperature to see if the antenna tilt can be reduced by reducing yoke heating. Repeat the experiment with an exhaust fan located in the upper pedestal room to further reduce temperature gradients in the yoke. The exhaust fan would draw air through the yoke arms and exhaust it outside the yoke.
2. If test 1 reduces antenna tilt, paint the concrete piers for one pad with titanium dioxide to see if tilt can be further reduced by reducing pier heating.
3. Remove the remainder of diurnal tilt with dynamic changes to the pointing coefficients based on temperature measurements.

VLBA Recommendations:

Remount the existing temperature sensors at Pie Town VLBA to improve their coupling with the structure.

Figures:

1. Specification sheet for Inframetrics Model 525 IR Camera.
2. Optical diagram for the Inframetrics camera.

References:

VLA Test Memorandum No. 156, VLA Antenna Tilt and Temperature Tests, C. Janes, March 1991.

VLA Test Memorandum No. 129, VLA Pointing Errors, S. von Hoerner, January 1981.

TABLE 1-1

SPECIFICATIONS - MODEL 525

Temperature Measurement Range	-20°C to 1500°C
Minimum Detectable Temperature	0.2°C
E-O Zoom Range	4:1
Isotherm	10, 20, 50, 100, 200, 500, & 1500 Ranges
Field of View, typical	14° X 18° with 4:1 Zoom
Frame Rate	*30 hz with 2:1 interlace
Spectral Range	8 to 12 microns
Detector	HgCdTe
Resolvable Elements per Line	>150
Lines per Frame	525 Raster, >200 IR 150 x 200
Focus Range	5" to Infinity
Detector Coolant	Liquid Nitrogen
Coolant Hold Time	>2 hours
Power Requirements	*12 volt Battery Or 110v AC
IR Scanner Size (HxWxL)	5" X 4½" X 6½"
Control/Electronics Unit Size(HxWxL)	5½" X 8½" X 8½"
IR Scanner Weight	4 lbs.
Control/Electronics Weight	5½ lbs.

*NOTE

For those countries using a CCIR format, the Inframetrics Model 525, colorizing system, colorizer with Iso/Line Scan and all TV monitors are adapted to a 50hz field rate with 625 horizontal lines per frame. Color is not available for PAL, SECAM and other formats. When color is required for countries using these video systems an RGB format is provided.

In addition, Inframetrics provides 220VAC power input for the following items:

Model 525 Power Supply
Colorizer System
Colorizer with Iso/Line Scan
Line Scan Integrator
Color Monitor (by use of 220VAC to 110VAC transformers)

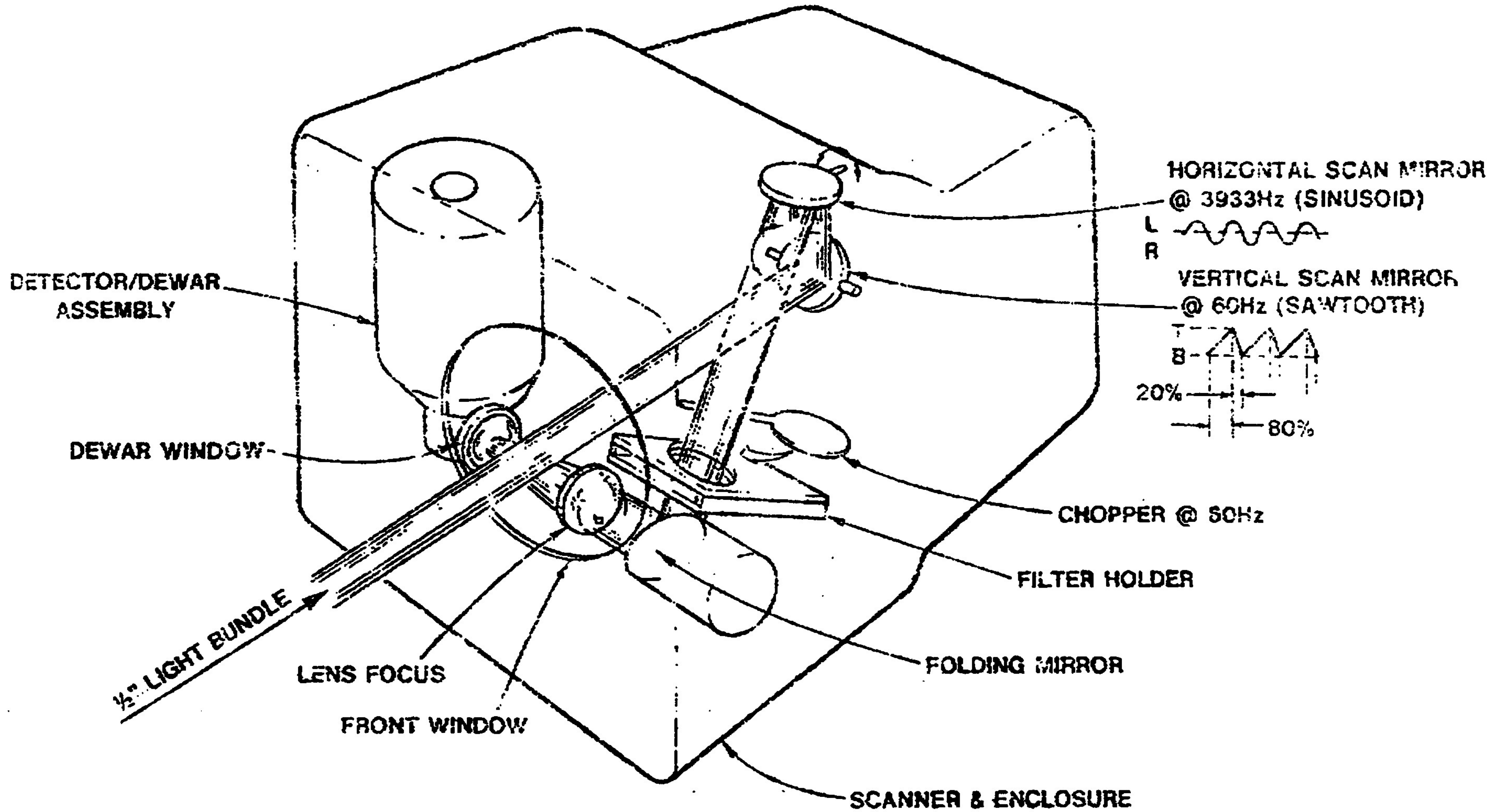

Fig. 1-1

OPTICAL SCHEMATIC - INFRAMETRICS MODEL 525