GBT MEMO 206

Instrument for Setting Radio Telescope Surfaces

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1 Introduction

The Green Bank Telescope (GBT) [1] is a 100-meter radio telescope under construction by The National Radio Astronomy Observatory in Green Bank, WV. The GBT incorporates a first-of-its-kind active surface that will be adjusted under a closed-loop laser metrology system [2] to correct surface deflections. The goal is to maintain a reflector surface accuracy of 0.220-mm rms in order to operate down to 3-mm wavelengths (100 GHz). The reflector is made up of 2004 individual panels, each of which is manufactured to a section of a 60-meter focal length paraboloid surface to an accuracy of 0.075-mm rms. The panels rest on 2209 motor-driven actuators that adjust the surface to correct for deflections in the telescope backup structure. A bracket on each actuator joins the corners of four panels, so each actuator moves the four adjacent panel corners as a single unit and thus the relative location of the four corners remains fixed.

Each panel is measured in a 4" X 6" grid on a coordinate measurement machine (CMM) before painting. A cardinal point, near each corner of the panel, is masked before painting in order to retain a reference to the CMM measurements. The CMM data is best-fit to the design surface, and the relative height of the "as built" cardinal points are calculated.

Radio telescope panels are traditionally adjusted to the fixed paraboloid shape, using conventional surveying techniques or photogrammetry. Fine adjustments are later made using a microwave holography technique. For the GBT holography, the goal is an accuracy of 0.100 mm on a 0.5 X 0.4 meter pixel spacing, i.e., holography can not resolve the step discontinuity between panels. Due to the unique architecture of the GBT, the panels do not have to be adjusted to the design paraboloid as accurately (since the final adjustments can be made by the actuators) as a fixed-surface telescope. However, the relative heights of the four panels is of greater concern. Laser rangers are used to measure retroreflectors, which are calibrated with respect to the cardinal points, located in the corner of a panel at each actuator--thus completing the final link in the chain between the CMM measurements and the telescope reflector paraboloid.

2 The Panel Setting Tool

A new instrument had to be designed for this application in order to set the relative heights of four panel corners to an accuracy of 0.050 mm, *in situ*. The accuracy of the instrument is around 0.015 mm, or 3 times better than the required mechanical adjustment precision. The instrument incorporates a dual-axis inclinometer, a sighting telescope, four digital indicators, a barcode reader, and a handheld computer. See Figure 1. The dual-axis inclinometer is used to reference the instrument with respect to the gravity vector. The sighting telescope is used to orient the instrument along a radial line to the vertex. This combination orients the instrument platform direction vectors. The four digital indicators measure the distance to each cardinal point with respect to the instrument platform. The barcode reader scans an identification number for each panel corner, which is used as the pointer to the offset calculated from the CMM data and the location to calculate the surface normal vector at that point for a given elevation angle of the reflector. The handheld computer is used to correct actual digital indicator measurements at the actual instrument orientation to distances that would be measured by an ideal instrument tangent to the surface.

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The instrument is attached to the center of the actuator bracket via a temporary stud extension screwed to a stud in the center of the bracket. This is simply to hold the instrument in place for the measurement, i.e., the orientation of the instrument is not important--except that it is oriented about its z-axis to point to the vertex. The instrument case and computer is operated from an adjacent panel in order to avoid distortions by standing on the panel under measurement. See Figure 2. The difference between the ideal and desired offsets is displayed for the technician to make mechanical adjustments, and thus bring the four corners into the desired relative positions. An adjustment tool was designed with a dial and pointer, calibrated in thousandths of an inch in order to facilitate making a precise adjustment and minimize iterations. See Figure 3.

3 Calibrations

The dual-axis inclinometers must be calibrated to an accuracy of about 15 arcseconds over the entire +/- 25 degree range. The inclinometer is mounted on a square lock and calibrated in the lab with respect to the block, before being mounted on the platform. This calibration is performed in a basement lab on an 8-foot surface plate leveled to about 2 seconds. Calibration of the dual axes is achieved by generating compound angles, measuring the inclinometer outputs, and doing a best-fit of the sine of the generated angles to a function with 10 terms--including cross terms. The compound angles are generated by a combination of a 21-inch sine bar and angle blocks used to rotate the inclinometers about the axis normal to the sine bar. The sine bar is set at 0, 15, and 25 degrees. Angle blocks are used to rotate the mounting block at 15-degree increments through a full 360 degrees, for each sine bar angle, for a total of 72 data points.

The instrument platform accurately locates the geometry of the four digital indicators and a mechanical reference for the inclinometer base block in order to orient the inclinometer with respect to the indicators. The instrument platform also has a mechanical reference to orient the platform and align the telescope to a reference target in the lab. The combination instrument platform and digital indicators are calibrated with only a level surface plate, and can thus be checked in the field. The hardware/software integration was tested using a 12"x12" granite sine plate and angle blocks to rotate the instrument about the axis normal to the sine plate.

4 Results

Since this was not in the original scope of work for the contractor (COMSAT Inc.), negotiations were required to implement the plan. NRAO developed and built three instruments and the work was performed by a joint team of NRAO technicians and COMSAT ironworkers. The specification was set at +/- 0.050 mm, which was limited by the precision of the mechanical adjustment. The corners were actually set to 0.030-mm rms, and the average time required to adjust a set of corners was 12 minutes.

5 Conclusions

By maintaining dimensional traceability of the GBT panels from the manufacturing floor to the telescope reflector, providing a cardinal point on the panels to facilitate matching the panels at the corners, and use of the panel setting tool and the laser metrology system, the GBT will be the first radio telescope surface to be set to high accuracy by dimensional metrology and at an unprecedented spatial resolution.

6 References

[1] http://info.gb.nrao.edu

[2] David H. Parker and John M. Payne, "Metrology System for the Green Bank Telescope", Proc. ASPE 1999 Annual Meeting, Vol. 20, p.21-24.

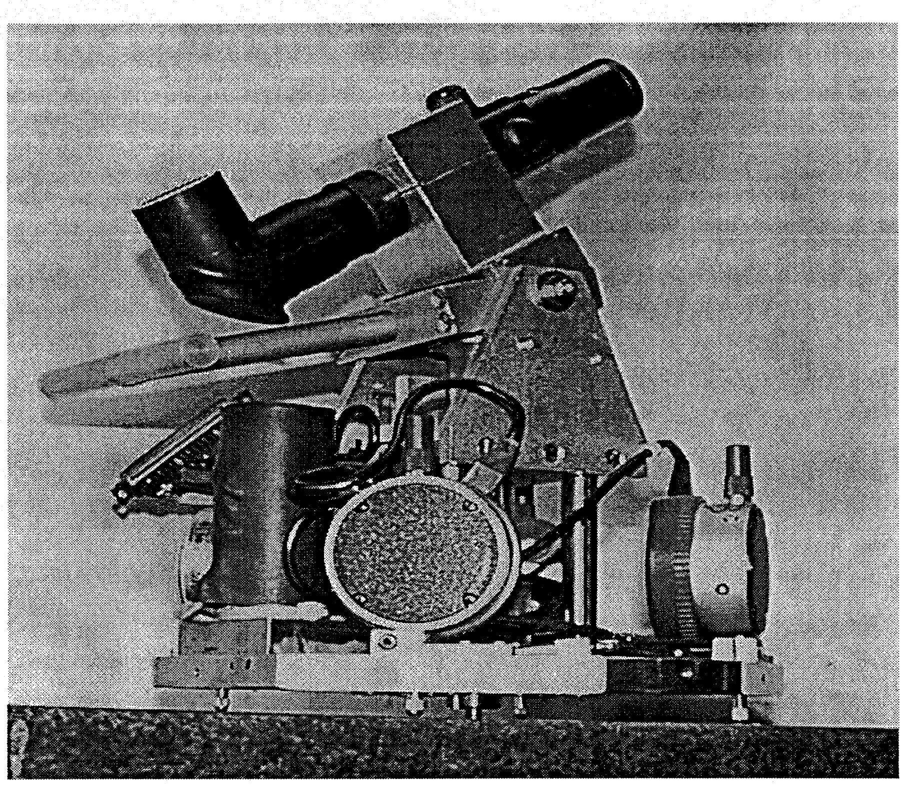

Figure 1

Figure 2

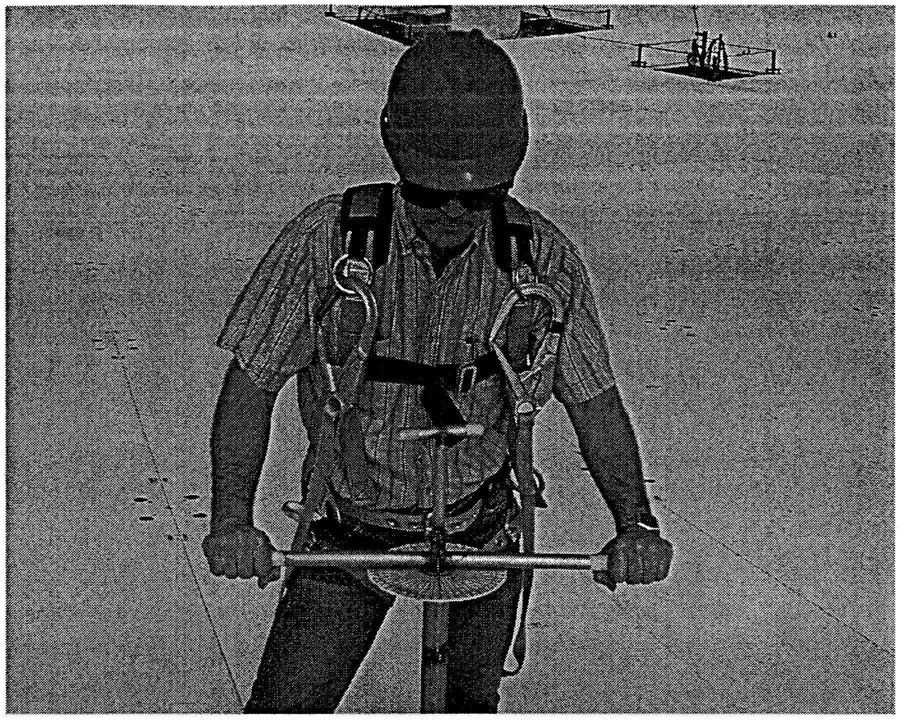

Figure 3