GBT MEMO 223

Green Bank site survey information

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Abstract

This report identifies all known survey information available for the National Radio Astronomy Observatory, Green Bank, West Virginia site. Most of the historical survey data, and all of the Antenna Metrology group survey data, has been incorporated into the STAR*NET least squares reduction software package. Notes on the use of the STAR*NET results are included.

1 Introduction

During the construction of the Green Bank Telescope (GBT), the Antenna Metrology group conducted many surveys around the Green Bank site. We also gathered as much additional data as we could find; including a wealth of historical information, provided by Sid Smith; the GBT soils report; the GBT location survey; contractor surveys; and a site survey.

All of this information is far too much to be included in this report, e.g., the STAR*NET listing alone is 161 pages. The detailed site information is filed in the GBT Archive, under file number ST047. The latest site report is on the CD under `100302\NRAO.LST`. GBT antenna surveys, and copies of the original field notes, are filed separately in the GBT Archive.

2 Surveys prior to the GBT

The NRAO site drawings identify a number of bench marks established early in the history of NRAO. Unfortunately, a number of the concrete bench marks have been disturbed or removed. It should be noted that the coordinates are in NAD27 state plane coordinates, in feet. The conversion from NAD27 to NAD83 is not straightforward, but the NGS provides free software (CORPSCON) to convert between coordinate systems.

In 1960, Geonautics did an extensive survey of the 140 Foot Telescope and established a network of reference bench marks around and on the telescope. Most of the ground reference bench marks have been destroyed since then. Geonautics bench mark G3, located on the hill north of the 140, has survived and has been protected by a wooden fence. The south bench mark, G12, which was used to establish the telescope alignment by Polaris measurements from G12 to a mark on the south deck of the 140, also survives and is protected.

In 1970, the Air Force did an extensive survey of the 140 Foot Telescope and established an additional bench mark, SITE, on the hill east of the telescope. They did many astronomical surveys from SITE and established the geodetic location and azimuth from SITE to G3, and SITE to G5. They transfered the elevation from first order bench marks in Cass to BANK (next to the school) and SITE.

In 1988, NOAA established three absolute gravity bench marks on the site and measured the absolute acceleration of gravity at these bench marks.

Richard Fleming generated a reference list of bench marks and coordinates. At least one of these (T-007) was found to be incorrect, so we recommend using the latest STAR*NET listing for all coordinates.

Sid Smith established reference azimuth bench marks at each of the interferometer stations, in order to align the telescopes after movement. These were established by Polaris observations, and the scribe marks were made for astronomical north.

3 GBT Surveys

In preparation for the GBT project, NRAO hired Triad engineering to do the soils report and survey the telescope location. This was where the error in Fleming's reference list was exposed, when they did not agree with the published coordinate for T-007. Unfortunately, one of the two Triad bench marks was destroyed early in the construction–which left the site without an azimuth orientation. The metrology group obtained the original Triad field notes and located several of the temporary bench marks, which allowed us to salvage the Triad survey. This survey was tied to a permanent bench mark, KING, located

SE of the GBT.

4 Site surveys

Dilly did a survey of the Green Bank site for mapping purposes. We obtained his field notes, but it should be noted that the survey did not close very accurately.

We obtained limited data on the survey for the Jansky lab addition, and no data for the Visitor's Center.

5 Antenna Metrology group surveys

The Antenna Metrology group conducted many surveys of the Green Bank site. These were primarily around the two outdoor test ranges, the 140 Foot Telescope test site, and the GBT. A level run was made between SITE and KING, which tied the GBT elevation to the Air Force elevation of SITE. Retroreflectors were established on the water tank and the microwave reflector on the mountain north of the GBT. These reference marks are visible from a large fraction of the site, and are handy for surveying such things as buried utilities.

The Antenna Metrology group did Polaris measurements at the GBT and established a reference azimuth[1]. During construction, the Antenna Metrology group surveyed the reference mark in the center of the pintle room floor and tied it to the laser monuments. Before the elevation encoder was mounted, the Antenna Metrology group established reference bench marks parallel to the center of the elevation bearings. This line was later used to survey the GBT and set the azimuth encoder.

6 STAR*NET reduction

Much of the historical data, and all of the Antenna Metrology group's data was entered into the STAR*NET reduction program. The program has many options, but the listing in ST047 (`100302\NRAO.LST`) was set to use the NAD83 State Plane coordinate system.

Note that the State Plane coordinate system is projected to the ellipsoid, so the actual distances between coordinates must take the grid scale factor into consideration[2]!

In addition to listing the input data, the software produces a comprehensive report, including: summary of controlling stations (p.56), adjustment results [coordinates](p.58), coordinate changes from entered provisionals (p.66), adjusted positions and ellipsoid heights [latitude, longitude, ellipsoid height](p.67), statistical summary (p.75), adjusted observations and residuals (p.75), adjusted coordinate observations (p.75), adjusted measured geodetic angle observations (p.76), adjusted measured distance observations (p.76), adjusted zenith observations (p.96), adjusted measured geodetic direction observations (p.112), adjusted grid azimuth/bearing observations (p.137), adjusted azimuths and horizontal distances (p.138), and convergence angles and grid scale factors at stations (p.153).

Note that STAR*NET requires an elevation for the 3-D adjustment. In some cases where the elevation was not known, a placeholder elevation of 820.0000 meters was used. **Any station with an elevation of exactly 820.0000 should be ignored.**

The only NGS bench mark in the area, with a published azimuth mark, is BANK. This is located in the corner of the fence at the Green Bank School. Unfortunately, the growth of trees prevented a clear shot from BANK to the reference azimuth mark located at the edge of the NRAO site, so Triad had to make it in two shots. Some of the Antenna Metrology surveys used this mark, but it was destroyed with the road project in the mid 90s. The best known azimuths are from SITE to G3 and laser monument ZY103 to ZY102.

It should be noted that the latest published coordinates of the third order bench mark, BANK, disagree with the STAR*NET adjustment by 0.235 meters. Several of the other published third order coordinates near the 140 Foot Telescope also disagree significantly, e.g., SCORPIO and TAURUS. T-007 is an A order NGS bench mark, which has been used by NGS for years as part of a GPS network monitoring crustal motion, and is considered to be the most accurate coordinate around Green Bank, so this is used as a control point in the STAR*NET adjustment.

Note also that NGS makes adjustments to the entire network and BANK has changed several times over the years. The elevation of T-007 changed significantly a few years ago. The CD contains historical runs of STAR*NET adjustments, which show the evolution of coordinates.

The Antenna Metrology group's version of STAR*NET-PLUS (5.112) is an older DOS program, and can be a little tricky to get set up. John Shelton has the software, manual, and some experience running it, but NRAO should consider purchasing the newer Windows version for future use.

7 Contents of ST047

1. CD ROM with all STAR*NET data
2. STAR*NET listing through 9/5/2002 surveys
3. Notes on GBT Polaris measurements
4. Triad soils report
5. NGS data sheets (check NGS web site for latest updates)
6. Notes on correspondence with NOAA
7. Geonautics survey report
8. Air Force survey report
9. Sid Smith's notes on geodetic positions of NRAO telescopes (note that these are in NAD27 coordinates)
10. Triad field notes
11. Dilly field notes
12. NOAA absolute gravity data sheets
13. Haystack-Westford survey report

References

[1] Richard L. Elgin. *1994 Celestial Observation Handbook and Ephemeris.* Elgin, Knowles & Senne, 1993.

[2] Russell C. Brinker and Roy Minnick, editors. *The Surveying Handbook.* Chapman & Hall, second edition, 1995.