GBT MEMO 169

Status of Pointing Tests on the 140 ft using the GBT Metrology System

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Abstract

Tests of new Unix based control and aquisition software revealed that the rate of measurements using the metrology rangefinders for widely spaced targets is approximately 1 per second. Short term (several min.) RMS fluctuations of ranges to static targets was about 60 μ, nearly independent of range. Range residuals from a model of the telescope for measurements to a reflector on the backup structure were approximately twice this or 120μ. These measurements were made on a muggy August afternoon.

1 Introduction

Since it will be some time until the GBT is available for tests of the metrology system, measurements of moving structures are confined to the 140 foot telescope. As of August 1997 there are only two operational laser rangefinders on the four stations around the 140 foot telescope. In addition, only one reflector was available on the moving structure although several static reflectors are available. This memo describes tests of cycling the rangefinders amoung several, widely spaced targets and monitoring the ranges to fixed and moving targets. The purposes of these tests are 1) to test new Unix based software for requesting and recording measurements and 2) to test the speed with which the rangefinders can measure different targets. The measurements reported were made during normal operation of the telescope. On a historical note, previous Unix and VXWorks software interfaces to the metrology system were made by Ray Creager and Tim Weadon in September, 1992 and Ed Meinfelder starting in April, 1993 (Parker, 1997).

2 New Data Aquisition Software

For these tests a multithreaded GUI based program was written to run on a Sparc workstation under solaris. This program allows the specification of patterns of targets for the different rangefinders and for the logging and graphical display of this data.

This software requests measurements using an RPC interface from a Windows NT based server that controls the rangefinders. This server returns measured ranges asynchronously. Separate servers are used to obtain rangefinder status and the commanded position of the 140 foot telescope. The measured ranges can be displayed or logged to a file for off line analysis. The user interface to this program is shown in figure 1.

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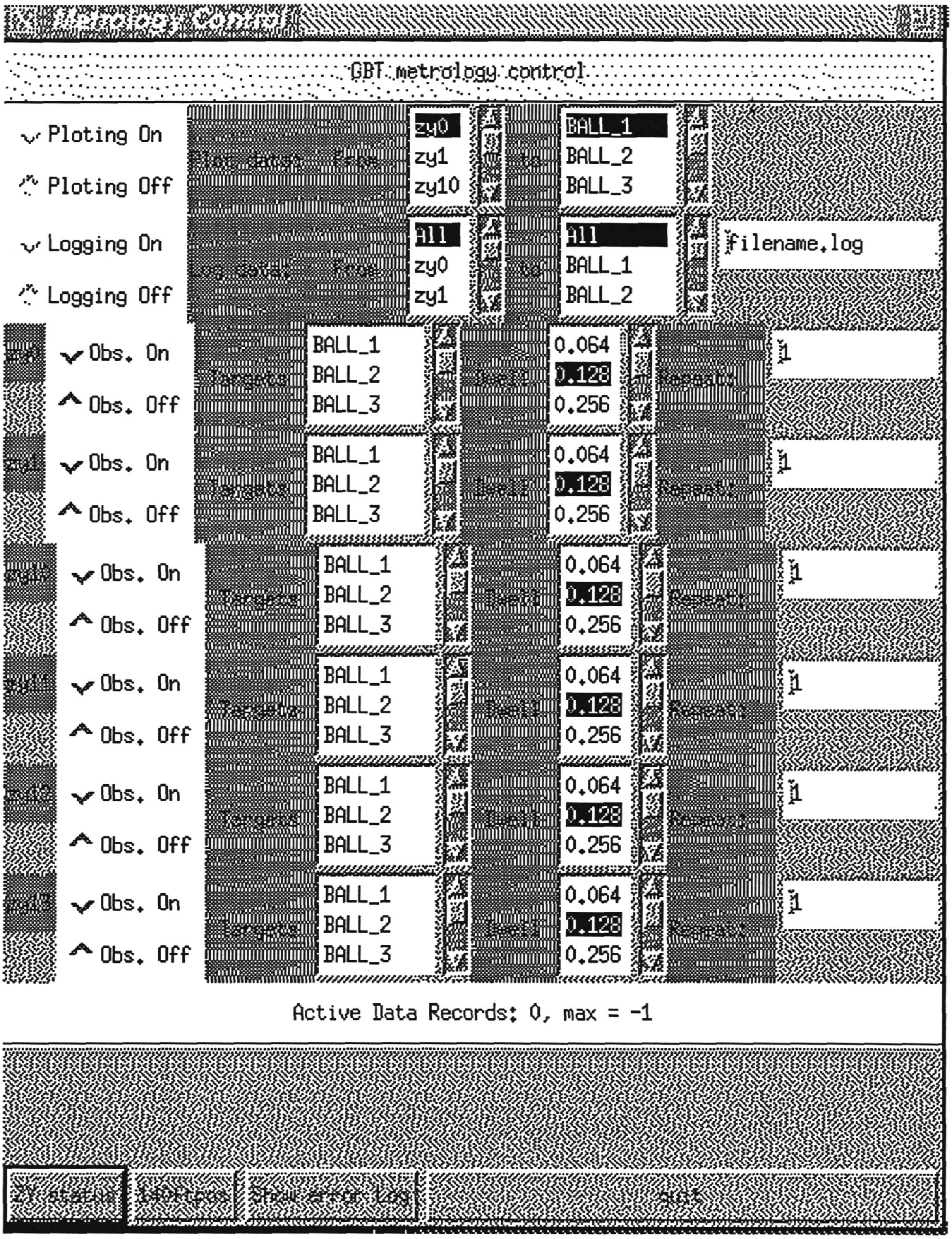

Figure 1: Graphical User Interface for 140 foot test control software.

3 Measurements

The measurements described in this memo were obtained on the afternoon of August 15. The weather was mostly overcast and hazy with occasional periods of sunlight. Winds were light.

The purposes of these tests were to test the new measurement control and acquisition software and to determine the speed with which the rangefinders can measure widely spaced targets. There were two rangefinders used which were placed on the easternmost station at the 140 foot (zy10) and the southernmost (zy13). There were two stationary targets used, Reflector, which is mounted on the mountain above the 140 foot and a retroreflector mounted on zy13. One retrosphere, Ball_1, was available on the 140 foot backup structure.

The measurement strategy was a simple one, each rangefinder would cycle amoung all of the available targets. In addition to the targets listed above, each rangefinder needed to make periodic measurements of an internal reflector for calibration purposes. The rangefinder on zy10 attemped measurments of Reflector, zy13 and Ball_1. Zy13 made range measurements of Reflector and Ball_1.

The measurements were made during normal telescope operations, a project Pheonix session. During most of the observations the telescope was tracking celestial positions. During this time the telescope was pointing in the north and north east. This geometry and the limited (60 deg) acceptance angle of the retrosphere meant that the rangefinder on zy13 could range Ball_1 during the entire session but from zy10 Ball_1 was never detectable.

4 Analysis

Ranges measured to static targets require little processing; variations in observed range can be interpreted as variations in the propagation delay. Long time scale variations are likely due to general changes in the air temperature and may possibly be calibrated. Short term fluctuations are likely due to small scale cells in the atmosphere and are expected to dominate the "noise" of the measurements.

For moving targets, the range residuals from model predictions are useful in order to evaluate the results. For the 140 foot telescope only a rigidly rotating model (GBT Memo 157) is available for the structure. The transformation between the coordinate system attached to the 140 foot reflector and a coordinate system fixed to the ground is:

$$\begin{pmatrix} x \\ y \\ z \end{pmatrix} = \begin{pmatrix} .999921 & -.009839 & .007809 \\ .012561 & .783222 & -.621616 \\ 0 & .621665 & .783283 \end{pmatrix} \begin{pmatrix} \cos\alpha & 0 & \sin\alpha \\ 0 & 1 & 0 \\ -\sin\alpha & 0 & \cos\alpha \end{pmatrix}$$

$$\left[\begin{pmatrix} 0 \\ 5.3308 \\ 14.9272 \end{pmatrix} + \begin{pmatrix} 1 & 0 & 0 \\ 0 & \cos\theta & -\sin\theta \\ 0 & \sin\theta & \cos\theta \end{pmatrix} \begin{pmatrix} u \\ v \\ w \end{pmatrix} \right] \qquad \text{Eq.1}$$

where $\alpha =$ -hour angle (positive west) and $\theta = 90°$ - declination. In the above (x, y, z) are fixed to the ground in the West Virginia South State Plane coordinate system where x increases towards east, y to the north and z opposite to the local gravity vector; the origin of the system is at the center of the bearing. (u, v, w) is in the frame attached to the reflector where u is in the direction of the declination axis, v is towards the focus and w is orthogonal to u and v forming a right–handed system; the origin is at the center of the declination shaft.

The model given in Eq. 1 was used to predict the range at the time of each measurment. The position used for the 140 foot was the commanded position interpolated to the time of the measurement.

There are two other sources of systematic error in these measurements: 1) excess path in the rangefinder internal calibration and 2) an excess path in the reflectors. The internal calibration of the rangefinder is to measure the delay to a target inside its structure; this delay is then subtracted from measurements made to external targets. In this internal calibration, the laser beam travels extra distance that it does not in other measurements. This excess path is subtracted in the calibration process resulting in an underestimate of the range.

The desired measurement point in the retrosphere is its center. Physically the light is reflected off its rear interior surface. This excess path overestimates the range. Preliminary, crude estimated of these systematic errors were used to correct the measured ranges. The excess internal path for the system on zy10 was assumed to be 0.1205 m and for zy13 0.1984 m. The excess path for the retroflector Ball_1 was assumed to be 0.172 m.

An additional complication is that the rangefinders only measure the phase delay and are subject to ambiguities of multiples of approximately 10 cm. When the range is nearly a multiple of the ambiguity it is quite likely that the rangefinder will pick the wrong "fringe".

5 Results

5.1 Speed of Measurements

These measurements were of a number of widely spaced targets as well as the internal calibration and thus constitute a good test of the speed with with the rangefinders can move between widely spaced targets. The rangefinders were instructed to repeat a cycle of measurements indefinitely. In these tests the on target integration was 128 msec. During a 47.5 min. (2859 sec.) period the rangefinder on zy10 made 2418 range measurements for a sustained rate of 0.8 measurements per second. This includes the overhead of one measurement using its internal calibration reflector once each cycle of three targets. In this mode, the rangefinders spend most of the time moving from target to target. This should be close to a worst case in that the targets are very widely spaced in angle and the small number of targets in a cycle increases the fraction of the time used for calibration.

5.2 Range Measurements

Measured ranges from zy10 to the static targets Reflector and zy13 are shown in figures 2 and 3. Note: the total range in the former is nearly ten times that in the latter whereas the short time scale scatter is similar. The path to Reflector, while much longer, is at an angle such that most of the air traversed is well above the ground. On the other hand, the path to zy13 is close to the ground. The similarity in the short period fluctuations shown in figures 2 and 3 suggest that most of the fluctuations occur near the ground.

A visual inspection of figures 2 and 3 suggests at least two types of fluctuations, a random, stationary component and fluctuations on time scales of minutes which are several 100 μ in size. A two minute segment of data during a well behaved period of the measurements from zy10 to Reflector ($\approx$ 1 km.) had an RMS variations of 69 μ; a similar period of measurements to zy13 ($\approx$ 100 m) had RMS fluctuations of 58 μ.

Range residuals from zy13 to Ball_1 on the 140 foot backup structure are shown in figures 4 and 5. The former includes a full ambiguity range and illustrates this difficulty. Figure 5 shows a more restricted range of residuals. The rough calibration described above has been applied to this data. Much of the structure in the range residuals is very periodic and is more likely to involve motions of the telescope not included in the commanded position used for the model. Two short periods (40 samples) during times in which this behavior was not apparent gave RMS fluctuations of 137 and 121 μ or approximately twice that of measurements to static targets. The cause of this difference is not known and further tests in which the motions of the telescope are better understood are required.

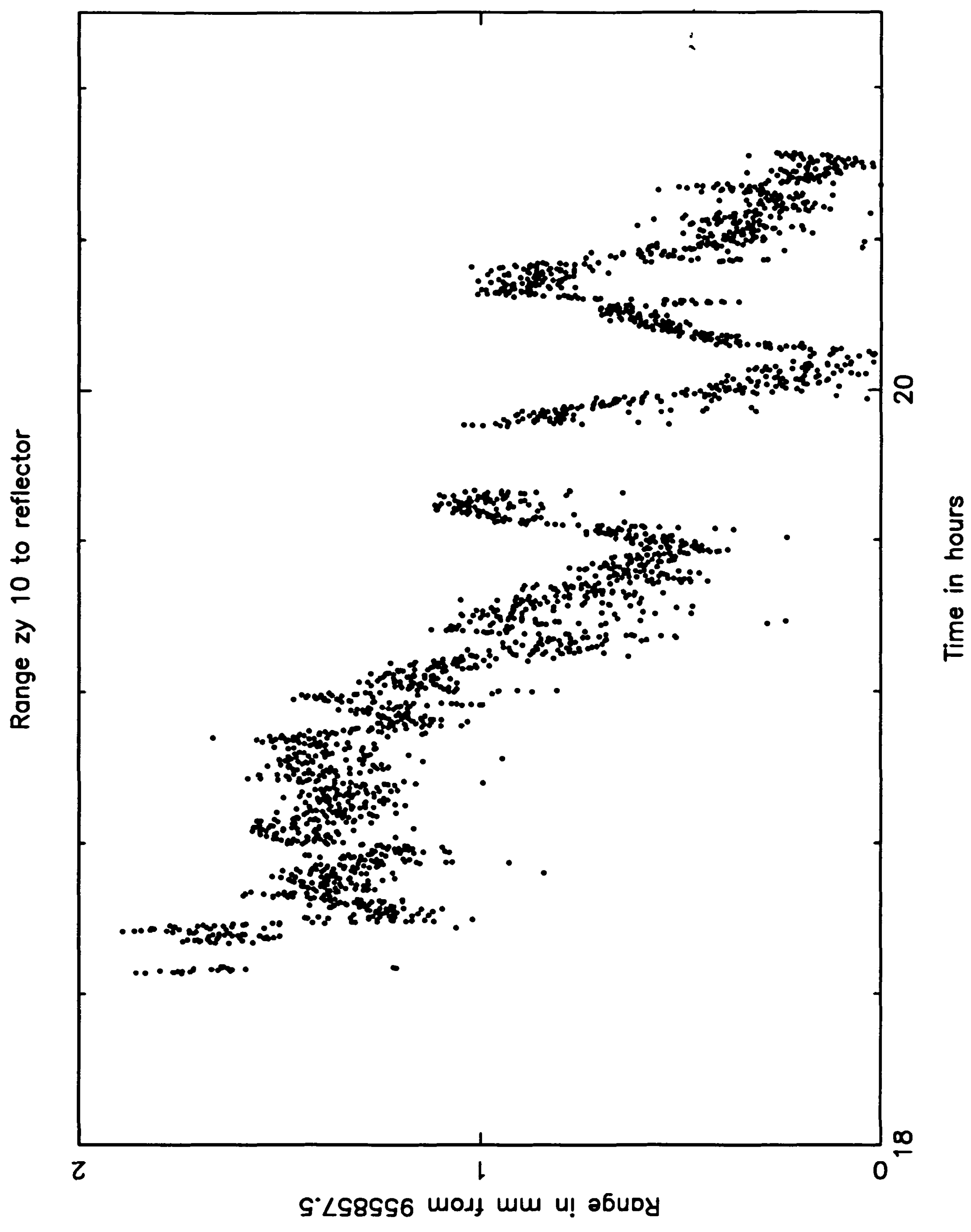

Figure 2: Range measurements from zy 10 to the reflector on the mountain ($\approx$ 1 km).

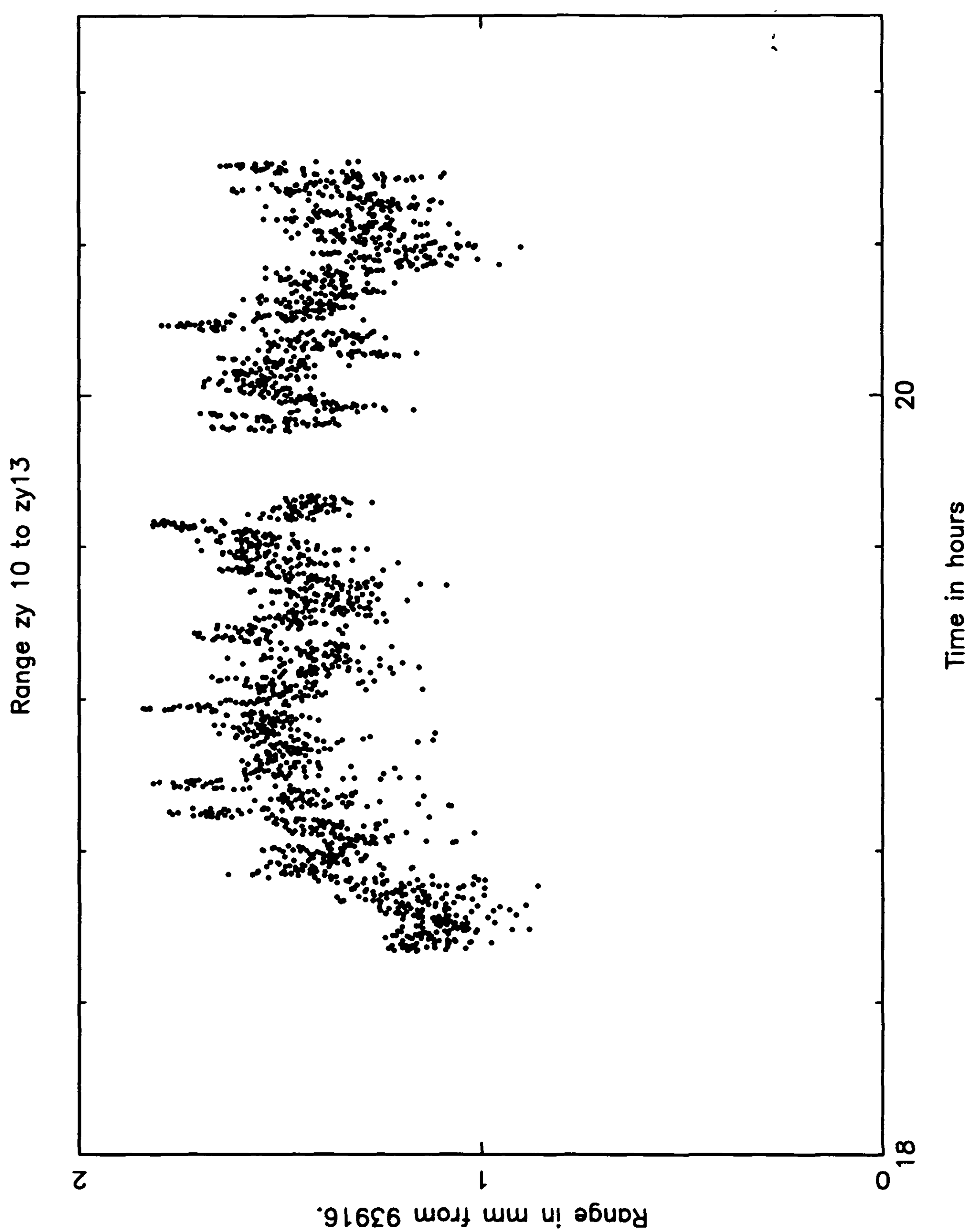

Figure 3: Range measurements from zy 10 to the reflector on rangefinder zy13 (≈ 100 m).

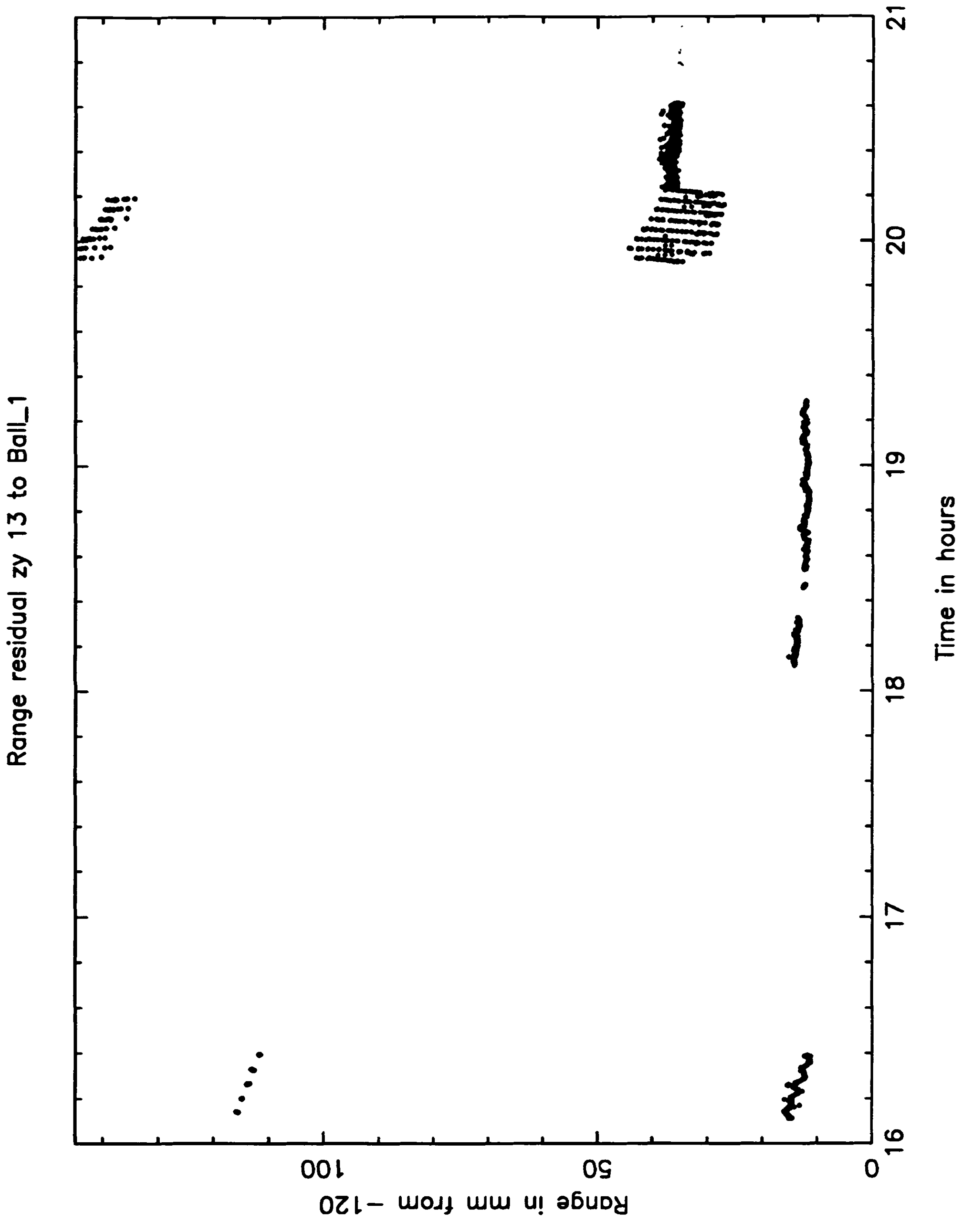

Figure 4: Range residuals from zy 13 to Ball_1 on the 140 foot telescope showing the full range of returned values. Fringe ambiguities are evident.

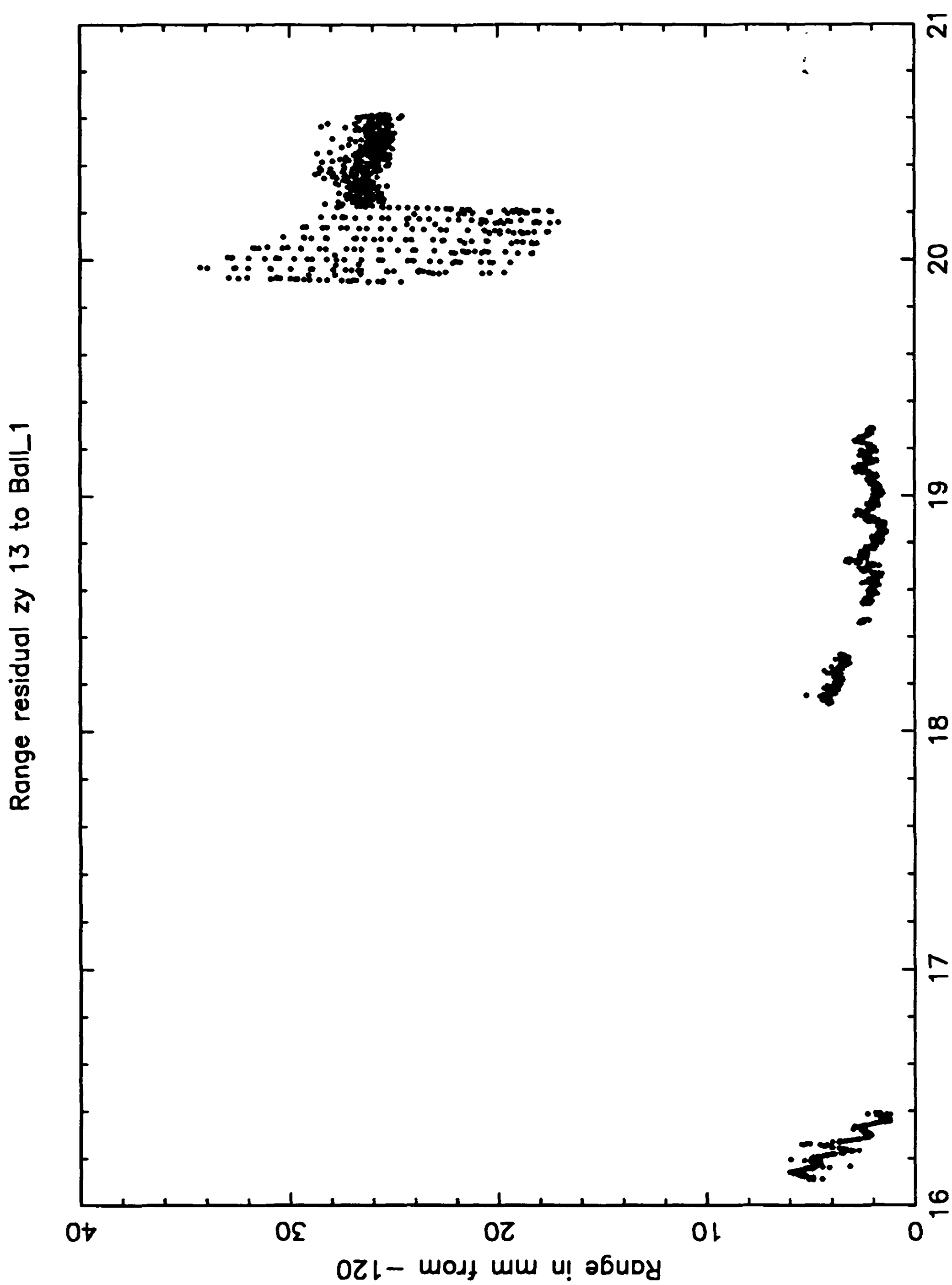

Figure 5: Range residuals from zy 13 to Ball_1 on the 140 foot telescope showing only the values around a single ambiguity.

6 Conclusions

These tests demonstrated the use of the metrology rangefinder systems by Unix based software connected by an RPC connection to the Windows NT metrology control system. The speed at which these systems can range widely spaced targets was determined to be about one a second. Even on a warm summer afternoon, the ranges to static targets show short term (min.) RMS fluctuations of about 60 μ nearly independent of range. Range residuals from a model of the telescope motion made while the telescope was tracking celestial objects was about twice that for static targets.

7 References

Parker, D. 1996, GBT Memo 157. A Status Report on The GBT Laser Demonstration At the 140Foot Telescope.

Parker, D. 1997, GBT Memo 166. The Green Bank Telescope Laser Metrology R&D Project: A Review and Bibliography