GBT S-band (2 GHz): Pointing Stability

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Abstract

The pointing repeatability and stability of the GBT are evaluated by pointing on 3C147 before and after the optics are adjusted and by tracking the half-power point of 3C295. The pointing is repeatable within 12″; although because the pointing model was not yet implemented this result is an upper limit. An *rms* of 2.″5 and 3.″8 are measured for the pointing stability over a time period of 30 min in elevation and azimuth, respectively.

1 Introduction

The pointing stability of the GBT is tested using the S-band receiver. Two tests are performed. The first experiment evaluates the pointing repeatability before and after the optics are adjusted. The second probes the pointing stability by tracking the half-power position of a point source. The brightness distribution of a point source is approximately a Gaussian. The maximum slope of a Gaussian occurs at the half-power position where variations in the system temperature are most sensitive. The observations and results are discussed in §2. The conclusion is in §3.

2 Observations and Results

2.1 Pointing Repeatability

The pointing repeatability was measured on 2001 March 02 by moving the main drives and the secondary optics from some nominal position to arbitrary positions and then back. The pointing was checked by running the GO procedure *peak* before and after these movements. The source 3C147 was used with a scan length of 30′ at a rate of 90′ per minute, with an integration time of 0.5 s. The focus-tracking and traditional pointing models had not been determined before these observations and thus the pointing should vary in time as the azimuth and elevation change.

The first experiment consisted of moving the secondary optics. The local pointing corrections (LPCs) were updated by performing a *peak* on 3C147. Then, the secondary optics (X, Y, Z) were changed from the nominal position of (-2.0, 0.0, 0.0) to three different positions and then back. A *peak* was performed before and after the motion. The measured pointing corrections were less than $12''$ in azimuth and elevation.

The second experiment consisted of moving the main (Az, El) drives. Again, after updating the LPCs the main drives moved the telescope about 10° and then back to 3C147. The corrections were less than $10''$ in azimuth and elevation. Larger moves were attempted but because of the slow slew rates the pointing model changed significantly during this time.

Because both the focus-tracking and pointing models were not implemented during these observations the results should not be taken too literally. But we can consider them to be upper limits for the repeatability of the pointing with respect to changes in the main drives and secondary optics.

2.2 Half-Power Point Test

The half-power point test provides a sensitive probe of how well the beam tracks a specified position with time. It therefore not only tests the pointing model but is also sensitive to problems in the focus tracking. For example, significant movements in the feed-arm should be detected. During these observations refraction, focus-tracking, and a traditional pointing model were being applied.

The pointing stability was measured on 2001 March 21 by tracking the half-power position of 3C295 by offsetting in azimuth and elevation by half of the FWHM beamwidth ($3'$). Before each track the GO procedure *peak* was used to update the LPCs. Then the GO procedure *track* was used to track the half-power position for 30 min offset $3'$ in elevation and then for 30 min offset $3'$ in azimuth.

Figures 1 and 2 plot the calibrated antenna temperature as a function of time for the offset in elevation and azimuth, respectively. Only the X linear polarization is shown. The *rms* is 0.31 K and 0.47 K for the elevation and azimuth offsets, respectively. Note that the azimuth plot has more structure and a higher *rms*. This is expected since the feed-arm should have larger motions perpendicular to the line of symmetry, which is in the azimuth direction. The contribution from random system noise is insignificant. An *rms* of ~ 0.025 K is measured off source using the cross scans from *peak*.

Assume that the antenna power pattern convolved with a point source on the sky is a two-dimensional Gaussian. The antenna temperature in one direction is then given by

$$T = T_o \, exp(-4 \, ln \, 2 \, (x/\Delta)^2), \tag{1}$$

where T_o is the peak antenna temperature, x is the position on the sky, and Δ is the FWHM. The slope of the Gaussian evaluated at the half-power point is

$$[dT/dx]_{x=\Delta/2} = -4 \, ln \, 2 \, (T_o/\Delta) exp(-ln \, 2) = -1.39 \, (T_o/\Delta). \tag{2}$$

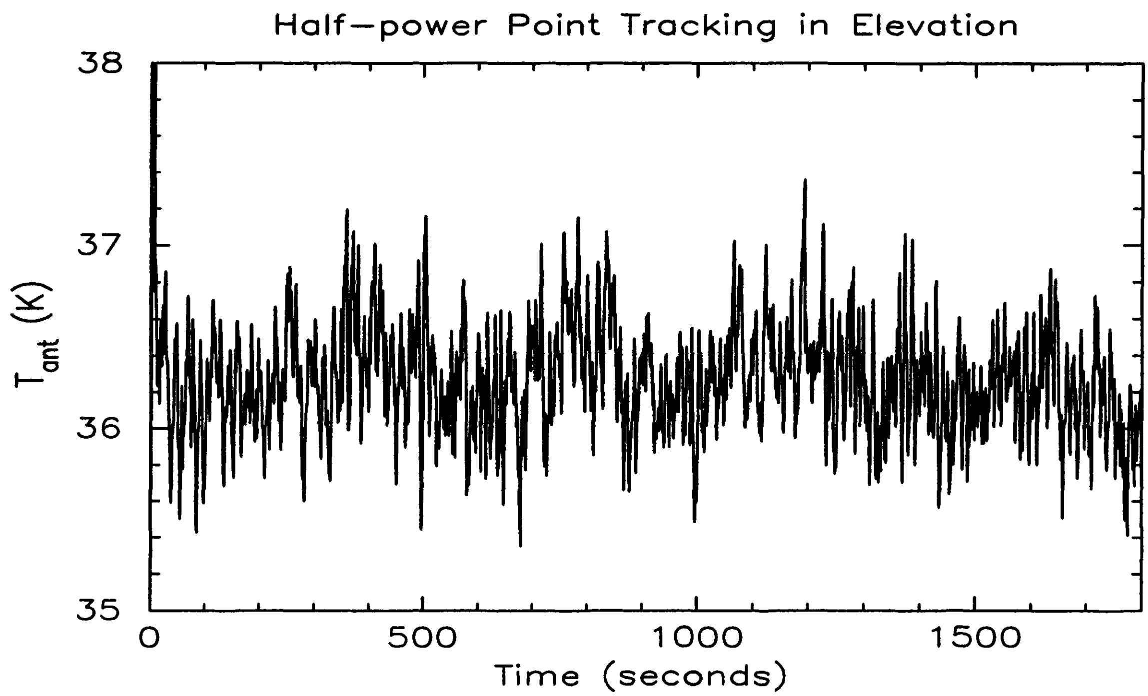

Figure 1: Calibrated antenna temperature of the half-power point of 3C295 versus time. The antenna position was offset $3'$ in elevation.

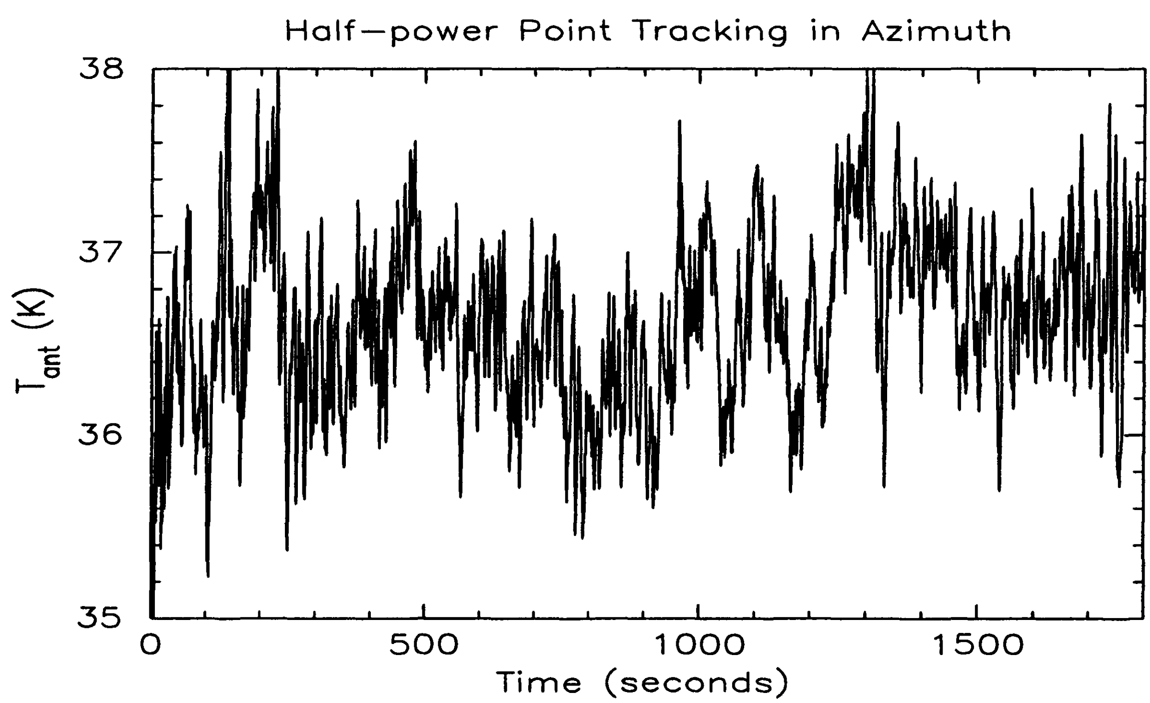

Figure 2: Calibrated antenna temperature of the half-power point of 3C295 versus time. The antenna position was offset $3'$ in azimuth.

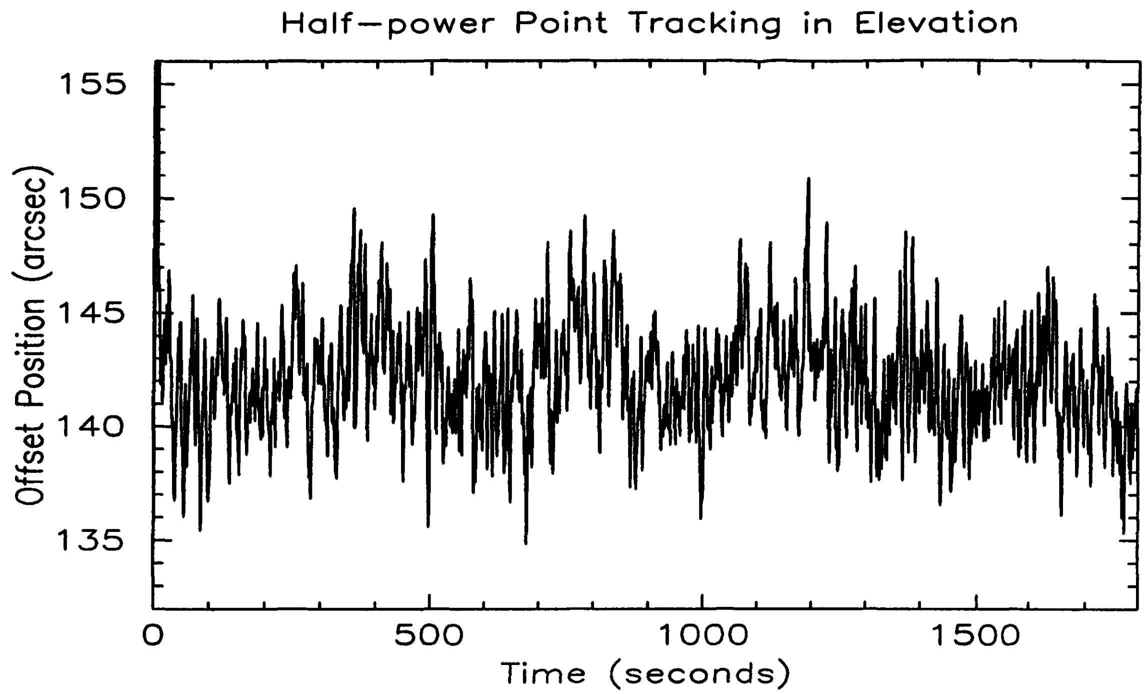

Figure 3: Offset position as a function of time for elevation. An antenna temperature of 3C295 of 32.4 K and a system temperature of 18.5 K were estimated.

For 3C295 at a frequency of 2 GHz, $T_0 = 32.4$ K and $\Delta = 6.'0$[1]. Therefore variations in intensity can be converted into pointing errors by dividing by 7.5 K per arcmin.

Figures 3 and 4 plot the calculated offset position on the sky versus time for the elevation and azimuth tests, respectively. A system temperature of 18.5 K has been estimated from the off source positions of the *peak* measurements. An *rms* of $2.''5$ and $3.''8$ are determined for the offset position in elevation and azimuth, respectively. In azimuth there are variations as large as $10''$ over a period of 25 s (see Figure 5).

Measurements of the feed-arm using the laser metrology system indicate that the feed-arm will drift on the order of 1 mm in 30 s (Parker 1999, GBT Archive L0555; Balser 2000, GBT Memo 204). That is, the feed-arm appears to sway from one location to another within minutes. The plate scale was empirically determined to be $1.'5$ per inch or $3.''5$ per mm. Using this scale the metrology measurements are roughly consistent with the variations determined by tracking the half-power point of 3C295. Notice that there are periods where the beam shifts about 5–10$''$. That is, the signal is not random and there appears to be structure in these plots.

Finally, note that the integration time was set to 0.5 s. Therefore the fundamental modes of the feed-arm cannot be analyzed by this dataset since these vibrations are on the order of 1 Hz.

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[1]The actual half-power beam-width is closer to $6.'5$. Therefore, the telescope was positioned closer to the peak with less sensitivity. However, this is only a 2% difference in dT/dx.

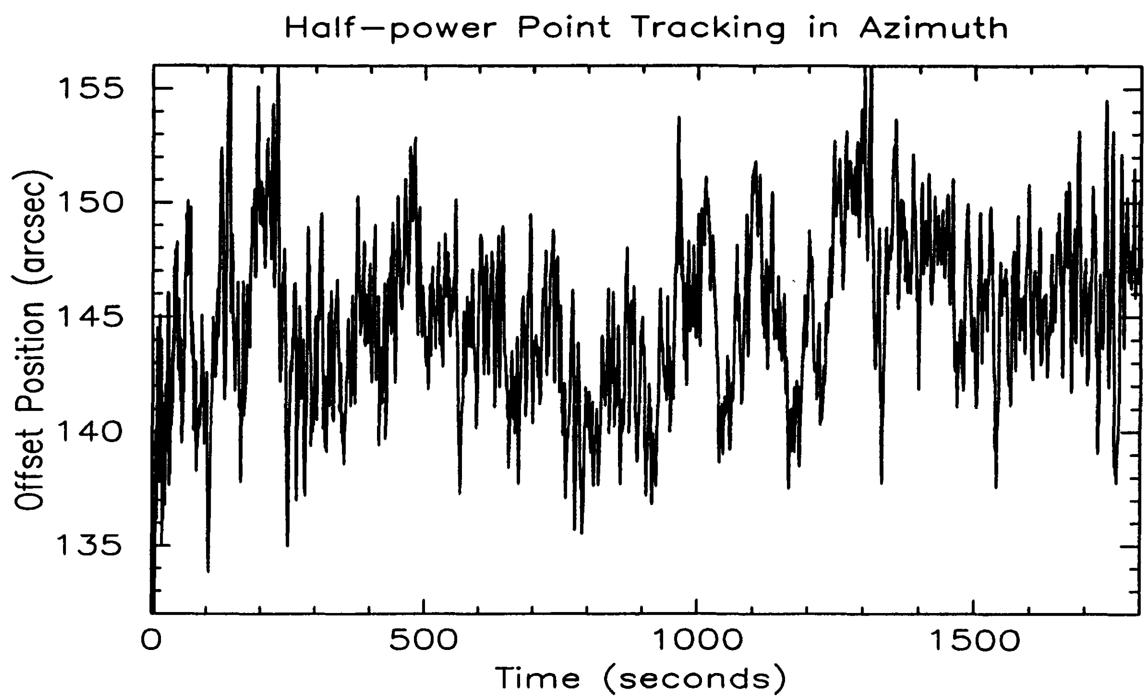

Figure 4: Offset position as a function of time for azimuth. An antenna temperature of 3C295 of 32.4 K and a system temperature of 18.5 K were estimated.

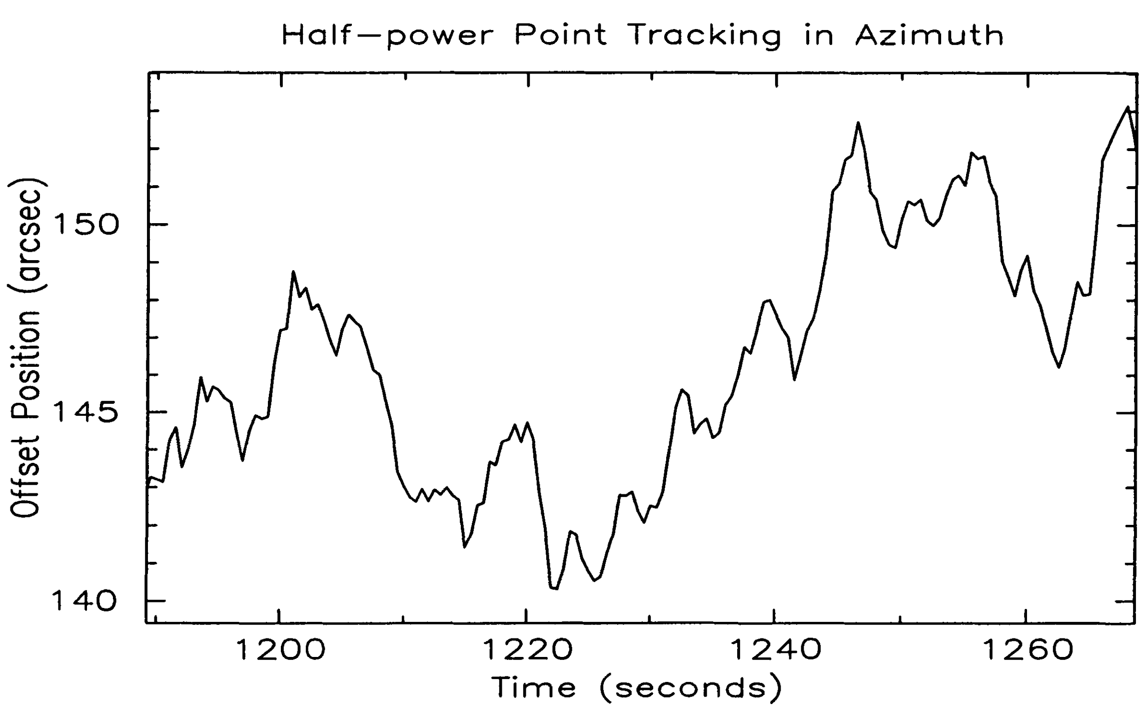

Figure 5: Same as Figure 4 with expanded scale.

3 Conclusion

Both the pointing repeatability and stability have been measured with the GBT Gregorian system using the S-band receiver. After significant changes in the main drives and the secondary optics the pointing was repeatable to within 12″. The half-power point in elevation and azimuth were tracked for 30 min each which produced an *rms* of $2\overset{\prime\prime}{.}5$ and $3\overset{\prime\prime}{.}8$, respectively.