GBT MEMO 127

NATIONAL RADIO ASTRONOMY OBSERVATORY
MEMORANDUM

DATE: April 17, 1995

TO: Robert Hall

FROM: J. M. Payne

SUBJECT: **GBT Dynamic Pointing Meeting**

Attached is the final report on the GBT Dynamic Pointing Meeting held in Tucson on March 30, 1995. The recommendations of the working group may be summarized as follows:

1. The simulation work done by Parvin and his colleagues should continue in order to demonstrate the expected reduction in the feed arm vibration induced by position switching. A factor of improvement of between 2 and 5 is expected.

2. NRAO should make it a top priority to complete instrumentation to monitor the feed arm movement. This instrumentation should be ready for installation as soon as the GBT is complete.

3. Analysis should begin as soon as possible on the effect of connecting the backup structure to the feed arm members.

4. The decision to make a tertiary reflector only for 40-50 GHz should be reconsidered. The tertiary should be a more general design and should work down to K band.

5. Someone should be commissioned to do a paper study on passive and active damping to control the feed arm vibration.

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Attachment

cc: J. Cheng
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Final Report on GBT Dynamic Pointing Meeting

J. M. Payne
April 3, 1995

A. Introduction

On March 30, 1995, a working group gathered in Tucson to discuss the implications of the vibration in the GBT feed arm and to make recommendations to the project manager as to what course of action to take. The participants were: J. M. Payne, D. Emerson, P. Jewell, J. Lockman, P. Napier, B. Parvin, R. White, L. King and J. Cheng.

The agenda of the meeting is given below:

1. Review of Switching Requirements:
   P. Napier, J. Lockman, D. Emerson, P. Jewell

2. Structural Considerations for Dynamic Pointing:
   L. King

3. Status of Dynamic Pointing Analysis:
   B. Parvin

4. Possible Improvements, If Needed

5. Action Items and Report

The motivation for the formation of the working group was the publication of the Dynamic Pointing Modeling and Simulations of the 100-m Green Bank Telescope, by Gawronski and Parvin, February 1995. In the report, the response of the telescope diffraction beam to a one degree step in azimuth is simulated and reproduced in Figure 9b. This response shows a lightly damped oscillation about the commanded position that continues for many tens of seconds. The decay is a simple exponential with values given in the following table. The time (t) is the time after the move command is given and ϵ is the peak to peak pointing error. A damping coefficient of 0.01 fits the data well. The frequency of oscillation is 0.75 Hz, although there appears to be a beat note between two frequencies quite close together.

Pointing Error After a One-degree Position Command in Azimuth

t (secs)	ϵ, p/p error (arc secs)	Frequency for which $\epsilon = 0.2$ BW p/p (GHz)
10	36	4.4
20	23	7.0
30	14	11.5
40	9	18.0
50	6	27.0
60	3.6	44.0
70	2.27	70.0

A brief review of the highlights of the meeting follows.

B. Review of Switching Requirements

This consisted of a review of the recently prepared document by Napier, *et al.* There was much discussion on the need to position switch and the group finally agreed to focus on the most critical cases which were defined to be:

1) VLBI Phase Switching - This requires the antenna to switch by about 2° to a calibrator once per minute.

2) Operation at 50 GHz.

3) Routine Pointing.

4) Holography.

The conclusions of the group as regards these most critical cases were as follows:

1) VLBI phase switching in azimuth cannot be supported at 43 GHz (a common VLBI observing frequency) with the antenna as delivered. The group was uncertain as to the highest frequency at which VLBI phase switching can be supported with the antenna as delivered.

2) Operation at 50 GHz with a 10% loss of integration time will require a position switching cycle of 16 minutes as compared with the more usual cycle of 1 - 2 minutes.

3) Routine pointing at frequencies of up to 15 GHz will be possible, but with a 50% duty cycle.

4) Any holography measurement taken with azimuth scans will take so long as to be impractical. It may be possible to use alternative scanning techniques such as scanning in elevation to reduce the overhead caused by feed arm vibration..

C. Structural Considerations for Dynamic Pointing

Lee King described the behavior of the structure that results in the feed arm vibration.

D. Status of Dynamic Pointing Analysis

Ben Parvin and Ralph White spent some time describing the servo and the dynamic pointing analysis to the group.

First, the conditions that were used to produce Figure 9b in the report of February 20, 1995 were spelled out. The conditions for that analysis are:

1. Acceleration limiting.
2. Velocity limiting.
3. Velocity shaping.

Not included, but possible, are:

4. Acceleration shaping.
5. Rate of change of acceleration limiting ("jerk limiting").
6. LQG algorithm.

Also presented was the most recent work by Gawronski and Parvin on the effects of stick/slip during tracking at sidereal rates. This was shown to be not a problem in inducing the arm vibration, although, when commanded to a stationary position, or tracking rates significantly less than sidereal, the stick/slip does induce feed arm vibration.

Parvin gave it as his opinion that the implementation of 4, 5 and 6 would give an improvement in the amplitude of vibration of the arm by a factor of between 2 and 5.

It was the strong recommendation of the group that Parvin and Gawronski continue the simulation work to demonstrate the potential improvement in performance, although recognizing that implementation on the actual telescope may yield different results.

E. Possible Improvements

Apart from the enhancements to the drive system described in "D" above, various other possibilities were discussed by the group. Most of these possible solutions are described in more detail in the memo by J. Payne of March 21, 1995.

1. Sense the Subreflector Position, But Do Not Correct.

   The instrumentation to sense the subreflector position is being developed. Either the laser rangefinders or the quadrant detector will measure the subreflector position with sufficient accuracy. The group recommended that the completion of this instrumentation be given high priority.

2. Sense the Subreflector Position and Correct.

   The movements detected by the instrumentation in (1), above, may be applied as pointing corrections to either the subreflector or a tertiary reflector. Apart from possible low level spectroscopy problems, this approach has the potential of greatly reducing the effect of the arm vibration. The status of the design of the tertiary reflector was unclear to the group.

   The recommendation of the group was to develop the design of the tertiary for as long a wavelength as possible and to ensure that all interconnections, both hardware and software, are in place as soon after commissioning as possible. Doubt was expressed that this approach would solve the VLBI phase calibration problem due to the movement of optical elements introducing additional phase jitter which would degrade the interferometer coherence.

3. Increase the Structural Damping.

   This solution attacks the problem directly. An additional feature is that all disturbances are damped out, including wind. Active damping was discussed and the additional mass that would be needed at the end of the arm was troublesome to the structural designers.

   The recommendation of the group was that someone be commissioned to do a feasibility study on both active and passive damping. An increase in damping from the present 0.01 to 0.02 would result in a dramatic improvement as shown in Figure 1. Six seconds after arriving at the commanded position, the residual peak to peak error is reduced to below 10 arc seconds. Very preliminary calculations indicate that this increase in damping could be achieved with a 5,000 lb. mass at the focal point.

4. Increase the Stiffness of the Arm Support.

The addition of cables or other supports was dismissed due to the lack of suitable attachment points. Lee King raised the possibility of attaching the base of the feed arm support to the backing structure. Apparently, this was done in the wind tunnel tests and the arm vibration was reduced by at least a factor of two. The consequences of such a fix are probably that the antenna with the active surface switched off will suffer from excessive gravitational deformations. If this fix is contemplated, then an early analysis is important as actuator positioning may be affected.

The group recommended that an analysis of the fix be accomplished as soon as possible.

F. Summary

The magnitude of the arm vibration for various fixes is summarized in Table 1. A factor of three improvement for the servo modification is taken (Parvin estimates between 2 and 5).

As may be seen, with 0.02 damping and the drive enhancements, the telescope position switching performance will be sufficient to support high frequency observations.

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Table I - Magnitude of ARM Vibration

Time Secs (t)	Peak to Peak Error (ARC SEC) a time t after A 1° Command in Azimuth					
	As Delivered Damping = 0.01	Damping = 0.02	Damping = 0.03	As Delivered x3 Improved	3x Improved +0.02 Damping	3x Improved +0.03 Damping
10	36	18	12	12	6	4
12	33	14.7	9	11	4.9	3
14	30	12.2	6.7	10	4.1	2.6
16	27	10	5.04	9	3.4	1.7
18	24	8.5	3.8	8	2.8	1.2
20	22	6.8	2.8	7.5	2.3	0.9
22	20	5.8	2.2	6.6	1.9	0.7
24	18	4.7	1.7	6	1.6	0.5
26	17	3.9	1.2	5.6	1.3	0.4

Effect of Damping on Settling Time
Figure 1