GBT MEMO 122

A Revised Description of the GBT Pointing System

D. E. Hogg and J. R. Fisher
February 7, 1995

INTRODUCTION

GBT Memo Number 103 presented a description of a number of individual and independent components of a pointing correction system which, when summed together, would provide a pointing system that would satisfy the high precision required to enable the GBT to operate effectively at high frequencies. This memo has been used in the planning and development of the system. Although it has been useful in general, a number of specific issues have arisen which require that the description of the system given in Memo 103 now be revised.

RULES

The two rules that governed the design of the pointing system are not changed. For emphasis, they are repeated here:

1. Particular components of the GBT pointing correction must each come from one and only one module. This rule might be relaxed in the future if it is found that there is a significant advantage to a weighted. Adder module that can handle correlated corrections from two or more modules.

2. The removal of a module from the system due to failure or by a judgement of the observer/operator must not result in system performance that is significantly worse than it would have been if the system had been designed from the start without the benefit of this module. In practice, this means that, under benign observing conditions, the outputs of all modules except the Traditional Model will be smaller that the expected error limits of the Traditional Model.

A SUMMARY OF THE CHANGES

There are three significant modifications to Memo 103 which are introduced here. First, the Ground Reference Laser System will be referenced only to the Traditional Model, and will not be expected to have knowledge of either the autocollimator or the quadrant detector in making its estimate of pointing error. It may however use information from the quadrant detector to estimate the deflection of the feed arm for retroreflector acquisition. Second, the concept of "focus-tracking" has been developed in much greater detail, to the point where the specification of the modules handling the equipment at both the prime focus and the secondary focus must be revised. Third, the special role of the Traditional Model is emphasized by linking it closely to the Antenna Manager.

There are a number of other changes incorporated in the system and reflected in the new block diagrams shown in Figures 1 and 2. In particular, the structure of the Commander has been redefined, and the tasks are now assigned to the Antenna Manager which is supervised by the Antenna Coordinator.

The concept of focus-tracking emerges from a restrictive definition of "pointing" which is introduced to better delineate the areas of responsibility in the general problem. The Commanded

Track is defined as the continuous series of directional position vectors and first and second vector derivatives as a function of time which specify the requested track of the telescope's plane wavefront with respect to a local, ground-based coordinate system. The complete description of the prime focus of the GBT requires both the position vector of the telescope's plane wave and the three coordinates of the point of maximum intensity after the first reflection. This definition must be augmented by including a requirement that the position of maximum intensity in the focal plane of the primary reflector as generated by a point radio source also be specified, either with respect to the ground or with respect to some fiducial point on the telescope structure.

We now define the dividing line between pointing effects and focus-tracking effects such that changes in the location of the prime focal point are called pointing corrections, while changes in the feedarm location will be called focus-tracking corrections. The pointing algorithm is concerned solely with controlling the Az-El drives so that the desired (refracted) target is imaged onto the point of peak gain for the primary mirror; the same pointing algorithm applies to both prime and Gregorian operation. In contrast, the two focus-tracking algorithms are concerned with manipulating the prime focus box or subreflector actuators in order to maintain the active feed at the (imaged) point of peak gain for the primary mirror.

The parameters of the pointing and focus-tracking modules must be calibrated in a consistent fashion, but they are independent modules. The pointing module is an "equation", but the focus-tracking module is better described as an "algorithm". For the Gregorian case, the output of the focus-tracking module is commands to the six subreflector actuators, while for the prime-focus case the output goes to the three prime-focus actuators; there is no output to the main Az-El drive in either case.

DESCRIPTION OF THE PRECISION POINTING SYSTEM (Figure 1)

Traditional Model

In its most basic mode, the GBT will be pointed using information only from its encoders and a weather station. These data will be used in three software modules. The first is the Traditional Model which contains of order 10 terms, each of which can be related to some specific part of the structure (e.g., encoder offset, azimuth track irregularities, collimation) except that it makes no reference to the behavior of the feed arm. This module provides the pointing corrections. The second module, the focus- tracking module, takes into account deflections of the feed arm; it maintains the gain. The third module is the refraction module which accounts for atmospheric effects. It is assumed to be located outside of the pointing system, as described in Memo 103. The output of the refraction module and the Traditional Model gives the initial estimate of the relationship between encoder reading and beam position on the sky for the particular weather conditions.

The Traditional Model will be used in all circumstances. All other modules will assume that the principal correction will be computed in the Traditional Model, and will therefore provide small offsets to the Traditional Model.

The Antenna Manager will ensure that all correction systems are supplied with both the Commanded Track and the output of the Traditional Model.

Autocollimator Module [Autocollimator; Alidade Model]

The definition of this module is unchanged from that given in Memo 103. It measures the horizontal position and tilt of the elevation encoder assemblies with respect to a ground-based reference system and reports the offset of these measurements from their expected track. The pointing correction from this module will not be used when the Ground Reference Laser Module is operating.

Active Surface Module [3-D Surface Designation System; Surface Model]

The definition of this module is unchanged from that given in Memo 103. It measures the actuator positions and reports the net effect of all actuator deviations from their expected positions in terms of resulting offset of the plane wavefront in the ground-based coordinates. If information about the surface is available from the Ground Reference Laser Module, then it will be used as the basis for the estimate in this module.

The Ground Reference Laser Module [3-D Measuring and Tracking System; Ground Reference Laser Model]

This module will provide an estimate of the offset between the direction of the radio axis of the primary mirror and the direction predicted by the Traditional Model. A set of lasers on the antenna arm will measure the distances to selected retroreflectors on the surface. The system will solve simultaneously for the deviations of the surface retros from the desired locations and for the position of the arm lasers with respect to the vertex line and to the focal point of the main reflector. The position of the arm lasers will be measured with respect to fixed monuments on the ground, either directly or through an intermediate stage involving retrospheres mounted on the rim of the dish.

Adder Module

The Adder sums vector corrections to the commanded track vector and sends the result to the pointing correction Triplexer.

Triplexer Module

This module takes the pointing corrections developed by the Traditional Model and either the Ground Reference Laser System or the Autocollimator and Surface Models and will distribute the corrections to the Main Drive, Focus-Tracking Module, and Tertiary Control according to their response speeds.

Main Drive Control System

This system interfaces with the servo system provided by RSI/PCD. The definition is unchanged from Memo No. 103. It maintains the antenna position on a track that causes the encoder readings to equal the sum of the commanded track and the low-pass component of the pointing correction.

RSI/SCCU

The SCCU consists of two servo controllers, the CCU for Az-EL and the SCU for prime-focus and subreflector control. Commands to both units consist of continuous series of directional position vectors, time reference, and the first and second derivatives with respect to time. These commands are incorporated into the actual servo position loops, after processing to limit bandwidth, position, velocity and acceleration to specified limits.

Coordinate Processor

The software module transforms the requested focus motion, in azimuth-elevation coordinates, into the coordinate system needed in the focus-control systems.

Prime Focus Control System

This system interfaces with the servo system provided by RSI. It passes commanded positions for the three actuators controlling the location of the feed assembly. The definition here is more restricted than in Memo No. 103, since the analysis of the nature of the required motion is incorporated into the Focus-Tracker Module.

Subreflector Control System

This system interfaces with the servo system provided by RSI. It passes commanded positions for the six actuators controlling the location of the Gregorian subreflector. The definition here is more restricted than in Memo No. 103, since the analysis of the nature of the required motion is incorporated into the Focus-Tracker Module.

Tertiary Mirror Control Module [Position Sensor; Tertiary Control]

This system controls the motion of the small, agile mirror located at the tertiary focus.

THE FOCUS-TRACKING SYSTEM (Figure 2)

The Antenna Manager and the Traditional Model are the same as for the Precision Pointing System. The Focus-Tracking System is concerned only with motions of the subreflector and of feeds at the primary focus.

Quadrant Detector

This device measures the direction to a point near the top of the feed arm with respect to a plane defined on the structure at the base of the arm, and reports the result to the Feed Arm Module for analysis. The output of the Quadrant Detector may also be sent to the 3-D Measure and Tracking System.

Feed Arm Module

The nature of the Feed Arm Module has been changed significantly from that described in Memo 103. The module in the present concept accepts information about the position of the feed arm either from the Quadrant Detector or from the Ground Reference Laser System. It then transmits the non-repeatable pointing correction due to deformation of the feed arm to the Focus-Tracker.

Feed Rotation Module [Position Sensor; Feed Rotation]

This module is required in order to permit rotation of individual feeds, or feed cluster, on the turret of the receiver house. It measures the position of a fiducial point on the active feed assembly with respect to the feed arm reference plane and reports the deviation of this point from the expected track to the Focus-Tracking Module.

Switching Offsets

This module enables offsets to the position of the prime focus feed or of the subreflector to be entered. These offsets will be provided to the Monitor and Control system by the telescope user, and may be desired, for example, for some types of position switching. If focus offsets are needed to suppress standing waves, they will be implemented here. Both types of offsets will in general be independent of the attitude of the telescope.

Focus-Tracking Module

The primary mirror forms a real image of a point source in the sky. When operating in prime focus mode, the prime focus feed must be centered on this image. The prime focus feed has three degrees of freedom. When operating in Gregorian mode, a real image of the first image is formed by the ellipsoidal subreflector, and the secondary focus feed must be centered on this secondary image by maneuvering the subreflector, which has six degrees of freedom. In the first stage, based on the bandpass—limited corrections from the multiplexer, coupled with an estimate of the gravity—induced deformations made on the basis of the structural model, the Focus-Tracker Module will issue a set of actuator commands to either the Prime Focus Control System or the Subreflector Control System. As measurements of the actual position of the feed arm and of the appropriate feed become available, this Module will incorporate them and refine its estimate of the position of the point where the field intensity achieves its maximum value.

PRECISION POINTING SYSTEM

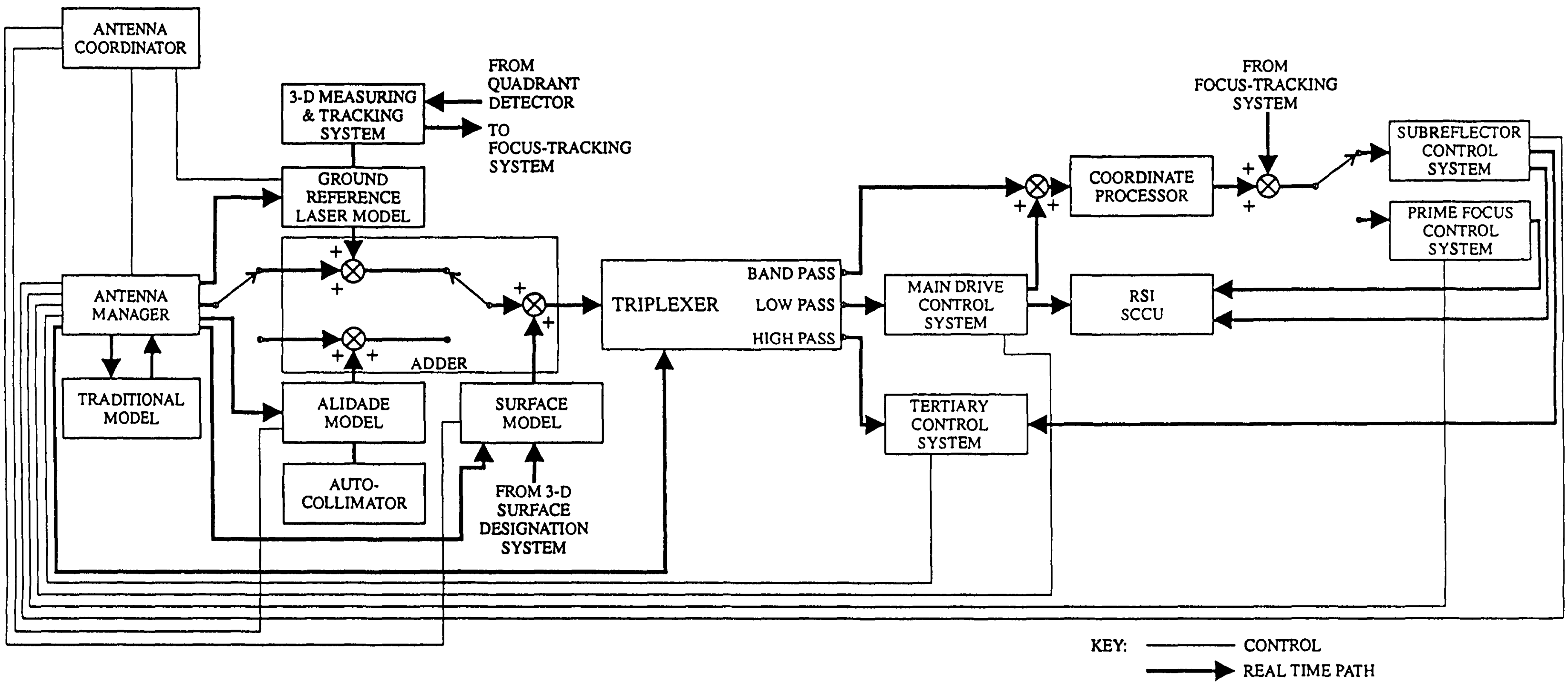

FIGURE 1

FOCUS-TRACKING SYSTEM

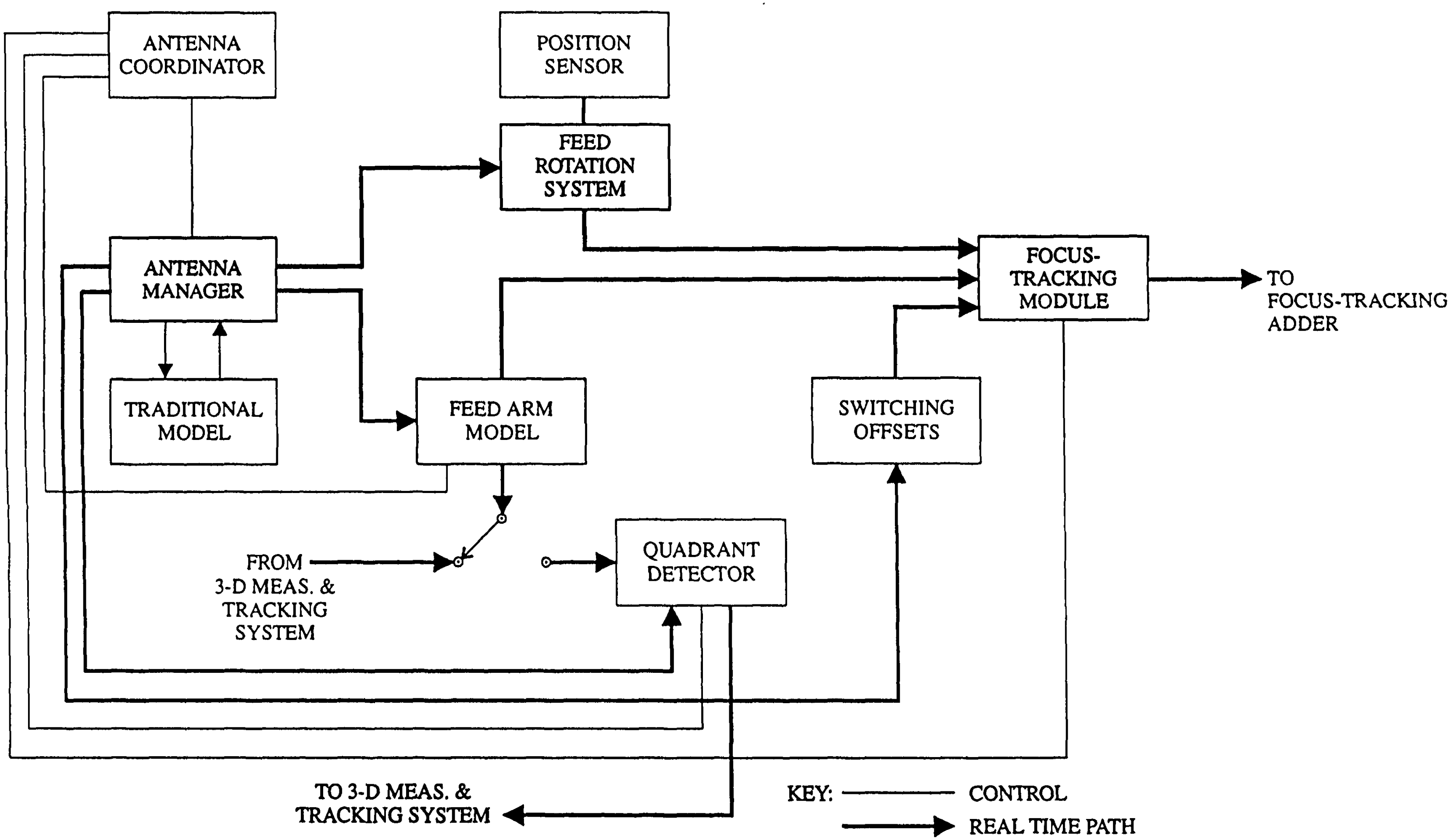

FIGURE 2