MULTIPLE MIRROR TELESCOPE OBSERVATORY

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MMTO Technical Memorandum 86-4

Re: Mount Computer Operator's Manual

From: Anthony D. Poyner

Date: 11 August 1986

The Operator's Manual for the MMT Mount Control Program has been completely revised, and is once more up to date.

Because the cost of duplicating and mailing a document of this size is considerable, the manual will only be issued internally. However, copies are available on request. Please write to the above address, or call our Department Secretary at (602) 621-1558 and we will send you a copy.

As always, I will be grateful if anyone noticing errors or omissions in the manual would notify me.

M O U N T   C O M P U T E R

O P E R A T O R ' S   M A N U A L

REV. 11 August 1986

Anthony D. Poyner

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SUMMARY OF THE MMT MOUNT CONTROL SOFTWARE

I. Introduction

This section is extracted (and slightly modified) from Technical Memo 82-8 by Weymann, Chamberlin and Ulich, first issued May, 1982. This summary is for occasional or first-time MMT users and is intended to acquaint them with the basic mount and secondary control systems.

II. Mount and Secondary Control: Basic Concepts

The altitude and azimuth drives are equipped with high precision encoders. Through extensive engineering tests, pointing algorithms have been developed connecting the Azimuth and Elevation encoder readings with the 1950 RA, Dec and time:

$$A = A\ (RA, Dec, t) \qquad (1a)$$

$$E = E\ (RA, Dec, t) \qquad (1b)$$

where A, E are the desired encoder readings and RA,Dec are the 1950 RA and Dec of the object being tracked. (Offsets may be internally entered in this algorithm as explained later.)

This is done in several steps: The 1950 RA,Dec are corrected for precession, nutation and aberration to give the current-epoch RA,Dec. The conversion to alt-az coordinates including latitude, atmospheric refraction, mount misalignment, encoder error, etc. is then made to obtain A, E. Differentiation of equations 1a, 1b with time then gives the desired drive rates. The updated transformation is calculated and a velocity command signal is fed to the mount servo system once every 50 ms.

The pointing algorithm was determined by requiring that stellar images fall on an arbitrary point (essentially, on the optical axis of the central guide telescope). Corrections to the algorithm for any individual instrument can be determined at the beginning of the night so that the images will, on the average, fall at any desired spot on the combined focal plane (e.g. an aperture of a spectrograph). The algorithm (1a, 1b) is found to produce absolute pointing which is currently 1.0 arcsec RMS and tracking accuracy in calm conditions such that the peak excursion of the image over 10 minutes is generally < 0.5 arcsec.

Consider a coordinate system rigidly attached to the MMT, with the X-Y plane coincident with the focal plane and the Z axis coincident with the optical axis of the guide telescope. Conceptually, we may imagine the guide telescope focal plane to coincide with the mean MMT focal plane where the instruments are mounted, though in actuality this focal plane is spatially distinct from the combined image plane. Let the Y axis point in the elevation direction and the X axis in the azimuth direction. Except at or near the north pole, over the small field of the MMT, lines of constant RA and Dec form an approximate orthogonal grid. Let PA be the parallactic angle - the angle between the vectors pointing towards increasing altitude and increasing declination (PA has no meaning at the zenith or the north pole). PA can be estimated from the chart shown in Figure ii-1. The (RA,Dec) being tracked (according to 1a, 1b) will remain at a fixed point in the focal plane. Nearby objects with slightly differing RA,Dec will appear to rotate around the object being tracked in the focal plane at a rate of PA′ (arcsec/sec) - as given in the following equation:

$$PA' = 15[(\cos(\phi)\ \cos(A)) / \cos(E)] \quad \text{(arcsec/sec)} \qquad (2)$$

where ϕ is the latitude.

Now consider any one of the six main telescopes. Each of the secondaries is equipped with manual or computer-controlled motions in the alt-az directions and readouts for these motions. The image from the kth telescope of the star which is being tracked will stay at whatever point in the focal plane it has been directed to (i.e. it will not "rotate" about any other point). <u>In practice</u>, gravitational and thermal deformations will cause the six images to wander with respect to the (fictitious) position of the guide telescope image. An open loop correction algorithm is typically used in the Telescope Coalignment System to reduce the rate at which the individual telescope images wander. Various autoguiding schemes are also available.

III. Mount Control Terminology

The following terminology, corresponding to the Mount Control Status Monitor Display, is used:

1. 1950 RA,Dec : These are always the mean 1950.0 RA,Dec of <u>the position being tracked</u>.

2. Current RA,Dec : (reference) These are the current epoch coordinates of the last RA,Dec coordinates entered by a "PRECESS" or a "CURRENT" command, or a "SEEK" from a catalog. They are the actual current epoch coordinates of the object being tracked ONLY if the RA,Dec offsets are ZERO. (The word "current" is thus somewhat misleading).

3. Actual RA,Dec : These are the current epoch coordinates <u>of the position being tracked</u>.

4. RA,Dec offset : The difference (actual RA,Dec - current RA,Dec) in <u>seconds of arc on the sky</u>.

5. Az-El offsets: Offsets in <u>seconds of arc on the sky</u> which are added to the A, E calculated using (1a, 1b), to arrive at desired telescope Az-El position.

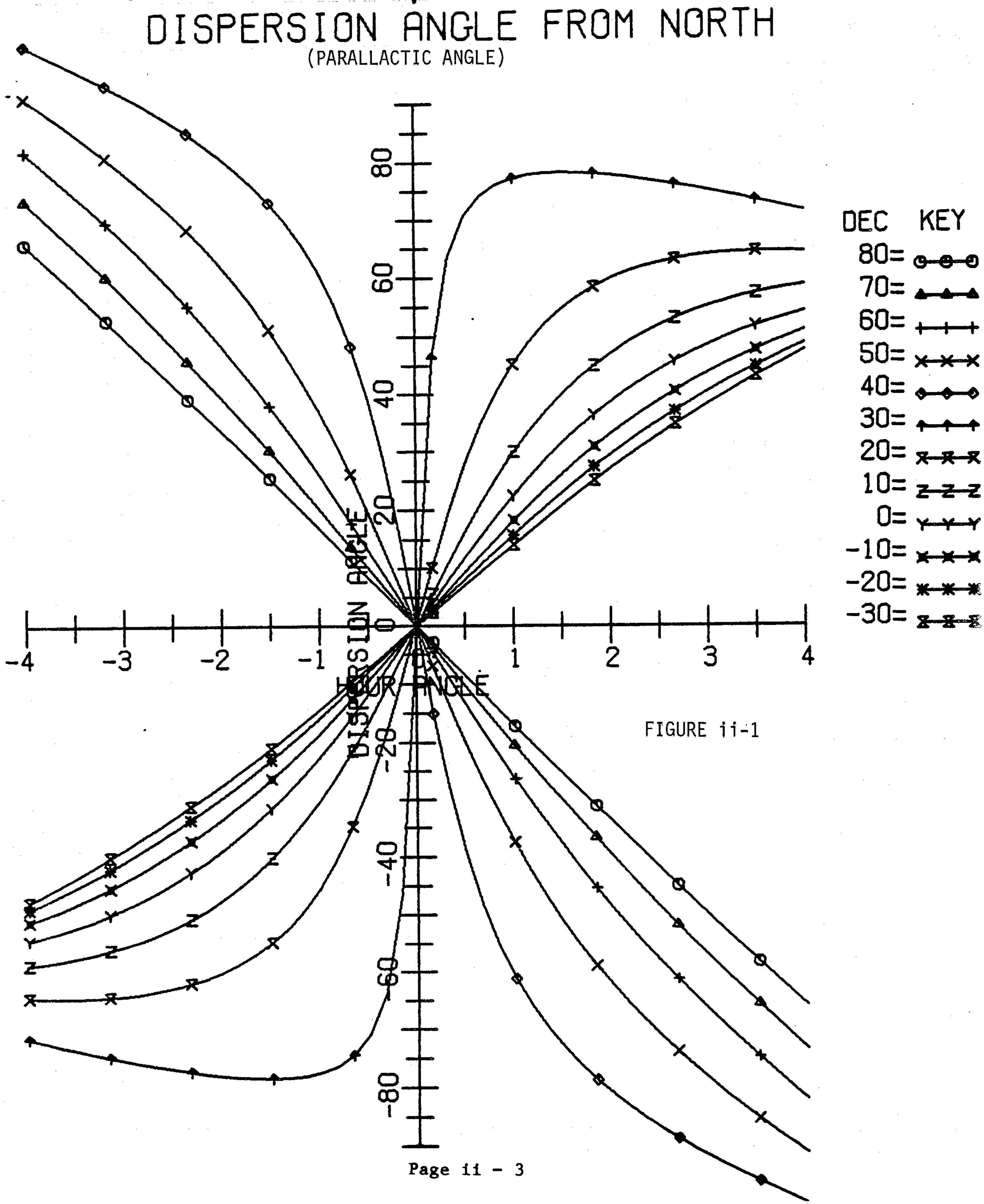
DISPERSION ANGLE FROM NORTH
(PARALLACTIC ANGLE)
DISPERSION ANGLE
HOUR ANGLE
80
60
40
20
0
-20
-40
-60
-80
-4
-3
-2
-1
0
1
2
3
4
DEC KEY
80=
70=
60=
50=
40=
30=
20=
10=
0=
-10=
-20=
-30=

FIGURE ii-1

IV. The Mount Paddle

A hand-held paddle is provided which has 4 buttons and a toggle switch. The toggle switch selects either "fast rate" or "slow rate"; these two rates can be separately set by the operator at the mount control computer terminal. The 4 buttons move the telescope either in RA,Dec (East/West, North/South) OR in Az-El (Left/Right, Up/Down): the desired mode can be selected by the telescope operator. Every time the paddles are used and the telescope is moved, the offset counters displayed on the status monitor are incremented by the amount the telescope is moved.

If the paddle is in the "RA/Dec" mode, these offsets are accumulated in the RA,Dec offset display. According to the definitions III(2, 3, 4) above, none of these paddle operations will change the "current" RA,Dec but the "actual" RA,Dec and the 1950 RA,Dec will change. This will cause a change in the Az/El drive rates through equations 1a, 1b, and the telescope will track the new position in the sky where it was directed by the paddle.

However, if the paddle is in the "Az/El" mode, pushing the paddle buttons will move the telescope in Az and El, i.e. offset it in Az and El: the Az/El offset counter will be incremented but the "RA,Dec offset counter" and hence the "1950 RA,Dec" displayed will not be changed: Accordingly, the telescope will continue to track at the rate appropriate to the object at which it was pointing before the paddle introduced offsets and the new object will not be tracked precisely but will rotate slowly about the old object position (which may or may not still be in your field).

V. Mount Commands

The following are the most important basic commands:

(a) PRECESS

"HH:MM:SS.SS DD:MM:SS.S PRECESS name"

where HH, etc. are the 1950 coordinates (other epochs can be used, but we assume that 1950 are the ones provided by the observer) and "name" is the name of the object. After this command is executed, the entered coordinates will be displayed, the precessed values will be displayed as the new "current coordinates" and, assuming RA,Dec offsets are zeroed, the telescope will move to the object. (It is possible to store 1950 coordinates on a floppy disk: see the FIND & SEEK commands and "object catalog" documentation.)

(b) The four commands "EE", "WW", "NN", "SS", e.g.:

xxxx.y EE

will move the telescope east (in the direction of increasing RA) by xxxx.y seconds of arc (not seconds of RA). This will be added to whatever was