MULTIPLE MIRROR TELESCOPE OBSERVATORY

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To: Distribution List

From: B. L. Ulich

Re: Mount Control Equations

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For your information, here are some of the MMT pointing equations:

*Start with current right ascension and declination and add offsets:

(1) ACTUAL DEC $\equiv \delta$ = CURRENT DEC + DEC OFFSET $(\hat{''})$

(2) ACTUAL R.A. $\equiv \alpha$ = CURRENT R.A. + $\dfrac{\text{R.A. OFFSET } (\hat{''})}{15\ \text{COS}(\delta)}$.

*Calculate the hour angle:

(3) H.A. $\equiv$ t = L.A.S.T. - ACTUAL R.A.

*Next convert to azimuth (A) and elevation (E) coordinates:

(4) MMT Coordinates: Longitude 110° 53' 29.1" West

Latitude (ϕ) 31° 41' 19.7" North

Altitude 2615.5 meters

(5) $\text{SIN}(E) = \text{SIN}(\phi)\text{SIN}(\delta) + \text{COS}(\phi)\text{COS}(\delta)\text{COS}(t)$

(6) $\text{SIN}(A) = -\text{COS}(\delta)\text{SIN}(t)/\text{COS}(E)$.

* To resolve the ambiguity in the quadrant of A, use the following:

(7) $\text{COS}(A) = \dfrac{\text{SIN}(\delta) - \text{SIN}(\phi)\text{SIN}(E)}{\text{COS}(\phi)\text{COS}(E)}$.

*Calculate the source position angle for the instrument rotator:

(8) $\text{SIN}(PA) = \text{COS}(\phi)\text{SIN}(A)/\text{COS}(\delta)$

and resolve the ambiguity in the quadrant of PA with:

(9) $\text{COS}(PA) = \dfrac{\text{SIN}(\phi) - \text{SIN}(\delta)\ \text{SIN}(E)}{\text{COS}(\delta)\text{COS}(E)}$.

*Now add AZ and EL offsets and refraction:

(10) TRUE EL = E + EL OFFSET

(11) APPARENT EL $\equiv$ E' = TRUE EL + REFRACTION

(12) REFRACTION = RCON $\cdot$ COT(TRUE EL) $\left[1 - 0.0011 \cdot \mathrm{COT}^2(\text{TRUE EL})\right]$,

where

(13) RCON ($\hat{''}$) = 21.71 $\cdot$ PTORR/ $\left[273.2 + (5/9)(\text{FTEMP} - 32)\right]$,

and

(14) TRUE AZ $\equiv$ A' = A + AZ OFFSET/COS(E').

*Calculate desired encoder readings:

(15) INSTRUMENT AZ = A' + AZ CORRECTION

(16) INSTRUMENT EL = E' + EL CORRECTION

(17) AZ CORRECTION = ao
+ (co + cotemp $\cdot$FTEMP/100 + AZ COLLIMATION)/COS(E')
+ np$\cdot$TAN(E')
+ ic$\cdot$TAN(E')SIN(A')
− is$\cdot$TAN(E')COS(A')
+ s2a$\cdot$SIN(2A')
+ c2a$\cdot$COS(2A')

(18) EL CORRECTION = eo + eotemp$\cdot$FTEMP/100 + EL COLLIMATION
+ ic$\cdot$COS(A')
+ is$\cdot$SIN(A')
+ tfc$\cdot$COS(E')
+ tfs$\cdot$SIN(E')
− PARALLAX .

*Calculate encoder readings:

(19) AZ ENCODER = 180° + AZ 2dial
− {(24-BITS-AZ + a1024$\cdot$ SIN $\left[1024(\text{24-BITS-AZ}) - \text{p1024}\right]$}

(20) EL ENCODER = (24-BITS-EL) + a1024·SIN[1024(24-BITS-EL) - p1024] - EL 2dial.

* The values of VELOCITY displayed on the lexiscope are the differences in encoder readings taken one second apart.

* Calculate the position control servo errors:

(21) AZ ERROR = INSTRUMENT AZ - AZ ENCODER

(22) EL ERROR = INSTRUMENT EL - EL ENCODER

(23) RADIAL ERROR = $\{[\text{AZ ERROR}/\cos(E')]^2 + (\text{EL ERROR})^2\}^{1/2}$.