Three local time systems will be discussed:
- Dipole Local Time (DLT) (Stone, 1964)
- Magnetic Local Time (MLT) (Fritz & Gurnett, 1965)
- Magnetic Equatorial Time (MET) (This report)

For a given dipole longitude \( \psi \) (degrees):

1. \[
\text{DLT} (\psi) = \text{DLT} (0^\circ) + \frac{\psi}{15} = \text{UT} + (289.8/15) + \frac{\psi}{15}
\]
   where UT = universal time (GMT) in hours, and 289.8\(^\circ\) is the geographic longitude of the north magnetic pole.

DLT is essentially the difference in dipole longitude between the spacecraft and the "magnetic prime meridian" (289.8\(^\circ\) E. longitude) plus the difference in geocentric longitude between the m.p.m. and the sun.

2. \[
\text{MLT} = \pm \frac{12}{\pi} \arccos \left( \frac{\hat{S} \times \hat{m}}{|\hat{S} \times \hat{m}|} \cdot (\hat{\mathbf{P}} \times \hat{m}) \right) + 12 \quad \text{(Note 1)}
\]
   where \( \hat{S} \) is the unit vector pointing to the sun;
   \( \hat{\mathbf{P}} \) is the unit vector pointing to the spacecraft;
   \( \hat{m} \) is the unit vector pointing north along the dipole axis.

MLT is essentially the difference in dipole longitude between the spacecraft and the sun.

3. \[
\text{MET} = \pm \frac{12}{\pi} \arccos \left( \frac{\hat{S} \times \hat{m}}{|\hat{S} \times \hat{m}|} \cdot (\hat{\mathbf{E}} \times \hat{m}) \right) + 12
\]

Note 1: The sign must be chosen appropriately in equations 2-4. This problem is not present in equations 1, 5, and 6.
(For comparison of the vector notations, DLT is given by:

\begin{equation}
 DLT = \pm \left( \frac{12}{\pi} \right) \arccos \left\{ \frac{|\vec{R} - (\hat{\vec{S}} \times \hat{\vec{R}}) \cdot (\hat{\vec{m}} \times \hat{\vec{R}})|}{|\vec{S} \times \hat{\vec{R}}| \sqrt{|\hat{\vec{m}} \times \hat{\vec{R}}|^2}} \right\} + 12
\end{equation}

where \( \vec{R} = \vec{R} \times (\hat{\vec{S}} \times \hat{\vec{R}}) = (\vec{R} \times \hat{\vec{m}}) \cdot \hat{\vec{k}}, \) etc.

and \( \hat{\vec{k}} \) is the unit vector pointing north along the earth's rotational axis.

The vector representations are usually not convenient for calculation, especially for DLT, for which the first formula given (1) is quite easy to handle. Analogous formulas for MLT and MET are:

\begin{equation}
 MLT = (\phi_o - \phi_s)/15. + 12.
\end{equation}

\begin{equation}
 MET = MLT + \Delta/15.
\end{equation}

where \( \phi_o \) = dipole longitude of spacecraft (degrees);

\( \phi_s \) = dipole longitude of sun (degrees);

\( \Delta \) = difference in dipole longitude between equator of real-field line and spacecraft position (degrees).

The dipole longitude of the sun can be obtained from the geocentric coordinates by an orthogonal transformation. The geocentric longitude of the sun is easily obtained from the universal time:

\begin{equation}
 \phi_s = 180(1 - T/43200)
\end{equation}

where \( T = \) universal time (UT), in seconds;

\( \phi_s \) = geocentric longitude of sun, in degrees.

The geocentric latitude of the sun (\( \lambda_s \)) is given by the following (Smart, 1944):

\begin{equation}
 \sin \lambda_s = (\sin \varepsilon) \left\{ \sin 2\pi \left( \frac{D-V}{365.24} \right) \right\},
\end{equation}

where \( \varepsilon = 23.445^\circ = \) inclination of rotational axis;

\( D = \) day of year;

\( V = \) day number of vernal equinox.

The dipole longitude of the sun is then obtained from these values using an orthogonal transformation into the dipole system defined by placing
the north dipole axis at geocentric coordinates $78.5^\circ N, 289.8^\circ E$:

\[
\begin{align*}
S_x &= \sin \Theta_s \cos (\phi_s + 70.2^\circ) \\
S_y &= \sin \Theta_s \sin (\phi_s + 70.2^\circ) \\
S_z &= \cos \Theta_s
\end{align*}
\]

(9)

\[
\begin{pmatrix}
S'_x \\
S'_y \\
S'_z
\end{pmatrix} =
\begin{pmatrix}
\cos \alpha & 0 & -\sin \alpha \\
0 & 1 & 0 \\
\sin \alpha & 0 & \cos \alpha
\end{pmatrix}
\begin{pmatrix}
S_x \\
S_y \\
S_z
\end{pmatrix}
\]

(10)

\[
\phi_s = \frac{(180/\pi)}{\arctan (S'_y/S'_x)} 
\]

(11) (Note 2)

where $\Theta_s = 90^\circ - \lambda_s$:

$\alpha = 11.5^\circ = \text{tilt of dipole axis}$;

$S = \text{unit vector to sun (geocentric coordinates)}$;

$S' = \text{unit vector to sun (dipole coordinates)}$

Computer programs are available (see writeups for METCON and METG/METD in 211 Downs) to compute $\Delta$, MLT, and MET. Subroutine METCON performs the calculations (7) and (8), calls subroutine DICON to perform the transformation (9), (10), and (11), and then calculates MET using (5) and (6). MLT is obtained by setting $\Delta = 0$. If MET is desired, subroutine METG (or METD) first calculates $\Delta$ by interpolating between values calculated from the GSFC (12/66) field model at 100 intervals in dipole longitude and 50 intervals in dipole latitude for

$60^\circ \leq |\text{dipole latitude}| \leq 850^\circ$.

The variations with altitude are included in the calculation, and are reasonably accurate for $0 \leq \text{altitude} \leq 1400$ km.

Note 2: Proper quadrant is chosen by FORTRAN function ATAN2(SY,SX).
"Magnetic Prime Meridian"

Greenwich Meridian

\[ \alpha \]

70.2°
Bibliography


Smart, W. M., Textbook on Spherical Astronomy, Cambridge (Eng.), University Press, 1944.


Also see (same title) Enrico Fermi Institute of Nuclear Studies preprint number EFINS 63-79.