4. Pre-Processing

4.1 Calculation of scan time

Scanning time should be calculated by scanning each raw image for subsequent processing. In order to determine scan time, satellite time in telemetry and ΔT data in OCTS are used.

4.1.1 Satellite time processing

(1) Preliminary inspection of satellite time

Satellite time is a counter figure (LSB = 2^{-5} sec.) in 32 bit and the count goes up every second. On the other hand, one major frame for OCTS is 0.905 sec. Therefore, satellite time during OCTS telemetry is either counted up every second by frame or the same time remains. When neither of these apply, this will be regarded as a preliminary inspection error.

Depending on scan timing, there may be rare cases in which the upper 16 bitword (ST1) only is updated in OCTS telemetry and the low word (ST2) stays unchanged. When this happens, time will be indicated with 2^{11} increase if there is an advance from low word. If this increase appears, modify data by subtracting 2^{11} -1 sec. from the low word.

(2) Correction of satellite time

Count figure of satellite time will be converted to actual time T (UTC) by the following equation, with satellite time correction information added to orbit data:

$$T = Ps \cdot (C - C_0) + T_0$$

Where Ps: Calculated satellite period
C: Satellite counter value
C_0: Reference satellite counter value
T_0: Reference Time (UTC)

However, for the cases where multiple sets of satellite time correction information exist, data within a valid period should be used according to time of the scene. Actual time correction should be performed by converting year, month and day format to continuous time series, using MJD (semi Julian calendar). Refer to section 4.2 for calculation of MJD.

4.1.2 Calculation of scan time

(1) Calibration of telemetry time in OCTS

ADEOS satellite time is counted up every second. On the other hand, major frame of OCTS has 0.905 period and is not linked with telemetry frame. For this reason, time offset ΔT(LSB = 2^{-6} sec) is measured and telemetered from the time satellite time was delivered to OCTS side to the time it corresponds to scan angle 0 of OCTS. Therefore, assuming satellite time of number *i* frame is *Tsi* and time offset when this happens is ΔT_i, T'_i, time for timing for scan angle 0 of that frame (-pitch direction) , can be expressed as the following equation:

$$T_i = Ts_i + T_0 + \Delta Ti \qquad (4.1\text{-}2)$$

In this equation, T_0 is offset time when satellite time is sent to OCTS. This value takes either 23.5 msec or 25.3 msec randomly. In actual operation, fixed value is used. The time mentioned above is the time when time was measured and frame timeTi which is actually is used should be the time at rotation angle 0 (geocentric direction) during imaging. That is, offset time dTso required to rotate by angle A_0 by (3/2•) of geocentric direction which is from the time ΔT was measured, should be added to the above. (Refer to Fig. 4.1-1)

$$T_i = Ts_i + T_0 + \Delta Ti + dTs_0 \qquad (4.1\text{-}3)$$

$$dTs_0 = \frac{A_0}{2\pi} P_s \qquad (4.1\text{-}4)$$

In this equation, scan period is put Ps (=0.905sec).

(2) Primary inspection of scan time

Depending on timing of time transmission, only ΔT may be reset without updating low word (ST2) of the satellite time. In this case, time calculated will be one second behind to actual time. When that happens, time should be adjusted by adding one second by looking at the time before and after.

In addition, calculated time has to go through primary inspection. In cases where scan time is not increased compared to the previous scan time within the extent of scan period ± tolerance permitted variable range (0.5%) (that is 0.900 - 0.910), this can be regarded as an error, however; since resolution of ΔT data, 2^{-6}=0.015625 sec. and is larger than tolerance, it should be regarded as an error in cases where scan time is not increased by the extent of 0.905±0.015625 after checking with this value (2^{-6}sec.). In case of error, linear interpolation should be performed to the scan time from the time of previous and subsequent scanning. Also, if telemetry for a given scanning is insufficient, linear-interpolation should also be performed to the scan time in the same manner for preliminary inspection error of satellite time.

(3) Smoothing of scan time

Since ΔT resolution is not adequate, scan time calculated above has 2^{-6} aberrance. This is equivalent to approximately 0.17 pixel and results in a variation of scan period within the range of aberrance. In order to smooth this out, the average of 11 points of distance moved should be used.

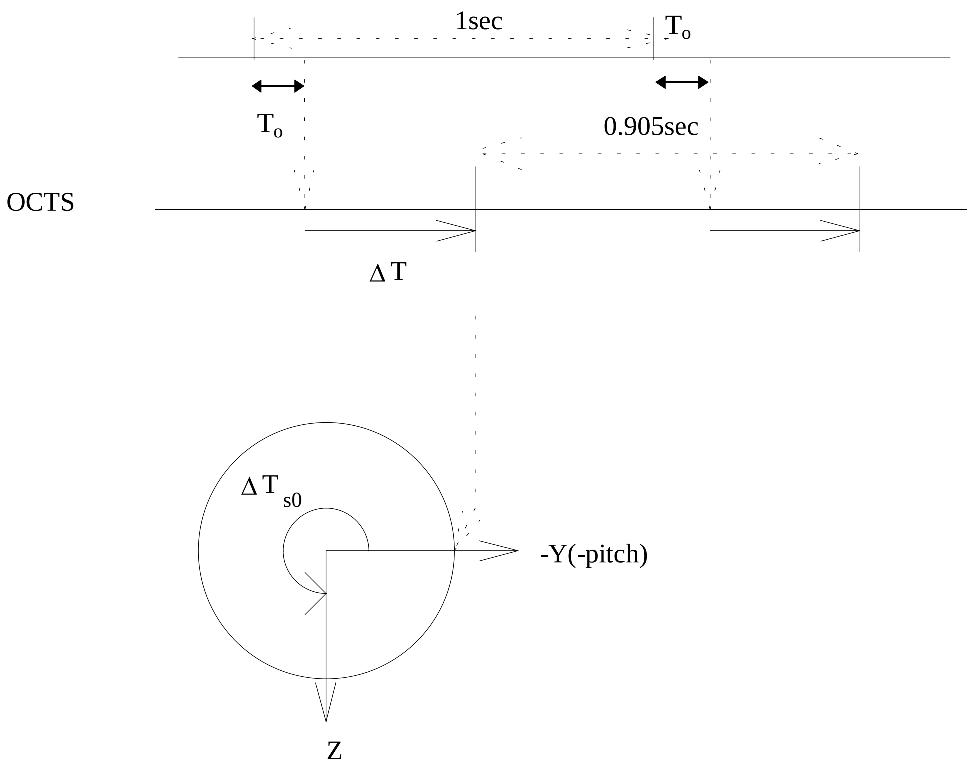

Figure 4.1-1 OCTS Frame Time

4.2 Processing of orbit data

In processing such items as geometric correction, satellite position and velocity corresponding to every one scan of raw image and scan time should be calculated. In order to perform this, orbit data in inertial frames (ECI) of each minute provided with level 0 data should be converted to Earth Coordinate Frames (ECR) and Lagrange interpolation be performed to interpolate these data to scan time data.

4.2.1 Conversion of orbit data to ECR Coordinates

Orbit data is given as the position and the velocity at every minute for inertial frames (ECI). Therefore, orbit data expressed as ECI is required to convert to earth frames (ECR) for geometric correction purpose. The following procedures are applied for this conversion;

1. Conversion from True of Date to Pseudo Earth Frames
   Conversion as to Greenwich sidereal hour angle

2. Conversion from Pseudo to "True" Earth Frames
   Conversion as to polar movement effect

(1) Conversion from True of Date to Pseudo Earth Frames

True of Date is a coordinate system based on instant true equatorial plane and the direction toward true vernal equinox. Orbit data is given by this coordinate system.

This is converted to pseudo earth frames which uses the direction toward Greenwich meridian as a base. This conversion is the rotation around the z-axis by true Greenwich sidereal hour angle θ_g. When coordinate system of True of Date is $\vec{X}_T$ and of pseudo earth frames is $\vec{X}_P$,

$$\vec{X}_P = B_1 \vec{X}_T \tag{4.2-1}$$

conversion Matrix is as follows;

$$B_1 = P_Z\left(\theta_g\right) = \begin{pmatrix} \cos\theta_g & \sin\theta_g & 0 \\ -\sin\theta_g & \cos\theta_g & 0 \\ 0 & 0 & 1 \end{pmatrix} \tag{4.2-2}$$

This equation is also used for calculating velocity in the inertia system in respect to satellite velocity vector.

True Greenwich sidereal hour angle θ_g is calculated as follows;

$$\theta_g = 100^\circ.0755425 + 360^\circ.985647346(T - 33282)$$
$$+ 0^\circ.29015 \times 10^{-12}(T - 33282)2$$
$$+ \Delta\theta + \Delta\mu \qquad (4.2\text{-}3)$$

T in this equation is MJD in the Atomic Time system (TAI). And $\Delta\theta$ is the correction term for the difference between TAI and World Time (UTI) given as follows;

$$\Delta\theta = 0.4178 \times 10^{-2} \text{ (deg./sec)} \times \text{ (UT1 - TAI) (sec)} \qquad (4.2\text{-}4)$$

$\Delta\mu$ is Equation of Equinox, and given as thus;

$$\Delta\mu = \Delta\phi \cos\varepsilon_T \qquad (4.2\text{-}5)$$

where, $\Delta\phi$ is angle distance between mean vernal equinox and true vernal equinox, and ε_T is true inclination of ecliptic measured from instantaneous true equatorial plane which is shown as follows with mean inclination of ecliptic ε_M and the equation of inclination of ecliptic $\Delta\varepsilon$.

$$\varepsilon_T = \varepsilon_M + \Delta\varepsilon \qquad (4.2\text{-}6)$$

ε_M is mean inclination of ecliptic measured from mean equatorial plane which is calculated by the following equation with Julian century, 1900 Jan 0.5 ET.

$$\varepsilon_M = 23^\circ 27' 08''.26 - 46''.845T - 0''.0059T^2 + 0''.00181T^3 \qquad (4\text{-}2\text{-}7)$$

T is hour (calendar hour) measured from 1900 Jan 0.5ET in Julian century, and is calculated as follows;

$$T = (MJD - 15019.5) / 36525 \qquad (4.2\text{-}8)$$

Since time data is in UTC and is stored in level 0 products as (UTC - TAI) and (UT1 - TAI) with orbit data, it should be used. For calendar hour, it is substituted by dynamic time TOT, which is expressed as TDT = TAI + 32.184 sec. Parameters for the notation $\Delta\phi$ and $\Delta\varepsilon$ are input from database. MJD (Modified Julian Date) is calculated as follows;

MJD = JD - 2400000.5 (JD : Julian Date)
JD = [365.25Y] + [Y/400] - [Y/100] + [30.59 (M - 2)]+ D + 1721088.5
+H/24 + MI/1440 + S/86400 (4-2-9)

where, Y is year, M is month, D is day, H is hour, MI is minute and S is second. For January and February, the following processing is applied previously.

January M = 13, Y = Y - 1
February M = 14, Y = Y - 1

(2) Conversion from "Pseudo" to "True" earth frames

"True" earth frames is considered as pseudo earth frames which has been corrected for the effect by polar movement. When $\vec{X}_T$ is "true" earth frames and $\vec{X}_P$ is pseudo earth frames,

$$\vec{X}_T = B_2 \vec{X}_P \tag{4.2-10}$$

is determined.

Conversion Matrix B_2 is given as follows;

$$B_2 = P_Y(-x_{pm})P_X(-y_{pm}) = \begin{pmatrix} \cos_x & 0 & \sin x_{pm} \\ 0 & 1 & 0 \\ -\sin x_{pm} & 0 & \cos x_{pm} \end{pmatrix} \begin{pmatrix} 1 & 0 & 0 \\ 0 & \cos y_{pm} & -\sin y_{pm} \\ 0 & \sin y_{pm} & \cos y_{pm} \end{pmatrix} \tag{4.2-11}$$

where, x_{pm} , y_{pm} are parameters to indicate volume of polar movement and as these values are so small that the followings can be written,

$$\begin{cases} \cos x_{pm} \approx 1 \\ \sin x_{pm} \approx x_{pm} \end{cases} \begin{cases} \cos y_{pm} \approx 1 \\ \sin y_{pm} \approx y_{pm} \end{cases} \tag{4.2-12}$$

The conversion Matrix B_2 is written as follows;

$$B_2 = \begin{pmatrix} 1 & 0 & x_{pm} \\ 0 & 1 & -y_{pm} \\ -x_{pm} & y_{pm} & 1 \end{pmatrix} \tag{4.2-13}$$

For velocity vector, above equation is also applied.
Parameters for polar movement are stored in Level 0 products with orbit data.

4.2.2 Interpolation Of Orbit Data

For later processing, orbit data of OCTS should be calculated scan line by scan line by performing interpolation of orbit data (satellite position and velocity). For this, Lagrange interpolation method should be used.

Generally, in Lagrange interpolation, if there is data set, $x = x_i$: $y = y_i$, y for arbitral x can be expressed as the following equation:

$$y = p(x) = \sum_{j=0}^{n} y_{i+j} N_j(x) \tag{4.2-14}$$

where $N_j(x)$ is polynomial expression of n degree,

$$\begin{cases} N_j(x_{i+j}) = 1 \\ N_j(x_{i+k}) = 0 \quad (k \neq j, 0 \leq k \leq n) \end{cases}$$

and expressed as the following n degree polynomial expression:

$$N_j(x) = \prod_{k=0}^{n} \frac{x - x_{j+k}}{x_{i+j} - x_{i+k}} \qquad \text{(k=j is not included)}$$

$$= \frac{(x - x_i)(x - x_{i+1}) \cdots (x - x_{i+j-1})(x - x_{i+j+1}) \cdots (x - x_{i+n-1})(x - x_{i+n})}{(x_{i+j} - x_i)(x_{i+j} - x_{i+1}) \cdots (x_{i+j} - x_{i+j-1})(x_{i+j} - x_{i+j+1}) \cdots (x_{i+j} - x_{i+n-1})(x_{i+j} - x_{i+n})} \tag{4.2-15}$$

When data interval of x_i is constant and $\Delta x = x_{i+1} - x_i$ and $s = (x - x_i) / \Delta x$, the above equation will be as follows:

$$N_j(x) = \prod_{k=0}^{n} \frac{s-k}{j-k} \qquad \text{(k=j is not included)}$$

$$= \frac{s(s-1) \cdots (s-j+1)(s-j-1) \cdots (s-n+1)(s-n)}{j(j-1) \cdots (j-n+1)(j-n)} \tag{4.2-16}$$

In case of orbit data, data interval of one set of data (1 day worth) is constantly one minute. (However, leap second is inserted, the interval between the first and last data is one minute and one second. The next number should be five degrees. In order to perform Lagrange interpolation accurately, data range should be selected evenly before and after the interpolation point. Therefore, in case of performing five degree interpolation, three points of data before and after the interpolation point should be used except for the end of data. Interpolation of orbit data is calculated by interpolating each element of orbit data (satellite position and velocity) of every minute for the time of scanning line.

4.2.3 Preliminary Inspection Of Orbit Data

Preliminary inspection will be performed for interpolated orbit data. The items to be inspected are as follows:

- Absolute value of geocentric distance. (upper and lower limits)
- Absolute value of satellite velocity (upper and lower limits)
- Variable satellite positions

(1) Inspection of absolute value of geocentric distance

When satellite position is (X, Y, Z), geocentric distance of satellite r is calculated as follows:

$$r = \sqrt{X^2 + Y^2 + Z^2} \qquad (4.2\text{-}17)$$

When equatorial radius is R and nominal satellite height of ADEOS is h,

$$r < R + h - E_h \quad \text{or} \quad r > R + h + E_h \qquad (4.2\text{-}18)$$

will be regarded as an error. E_h is within tolerance of satellite height.

(2) Absolute value of satellite velocity

Nominal velocity V_n (absolute value) of satellite when period of rotation is T_s is expressed as follows:

$$v_n = 2\pi(R + h) / T_s \qquad (4.2\text{-}19)$$

On the other hand, when each coordinate element is (X, Y, Z), actual velocity v is expressed as follows.

$$v = \sqrt{X^2 + Y^2 + Z^2} \qquad (4.2\text{-}20)$$

When the difference of these is greater than certain value, that is when

$$|v - v_n| > E_v \qquad (4.2\text{-}21)$$

this will be regarded as an error. For this equation, E_v is within the tolerance of satellite velocity.

(3) Variation of satellite position

Suppose satellite position and velocity at certain interpolation point is $(X_i, Y_i, Z_i)(\dot{X}_i, \dot{Y}_i, \dot{Z}_i)$. Expected satellite position at the next interpolation point with OCTS scan period s, this should be close to $(X_i + \dot{X}_i s, Y_i + \dot{Y}_i s, Z_i + \dot{Z}_i s)$. When the difference from actually interpolated satellite position is $(\Delta x_i, \Delta y_i, \Delta x_i)$ (= $(X_i + \dot{X}_i s - X_{i+1}, Y_i + \dot{Y}_i s - Y_{i+1}, Z_i + \dot{Z}_i s - Z_{i+1})$)

and lag distance is d > E_d, $d = \sqrt{\Delta x_i^2 + \Delta y_i^2 + \Delta z_i^2}$, this will be regarded as an error. In this equation d is acceptant failure.

4.3 Calculation Of Sun Position Vector

In order to perform atmospheric correction, it is necessary to calculate sun angle at the point of imaging. Sun elevation also needs to be calculated in order to determine observation range of daylight area. Therefore, sun position for ECR should be preliminary calculated.

(1) Calculation of apparent ecliptic longitude and geocentric distance

Apparent ecliptic longitude r_s of the Sun and geocentric distance at ecliptic coordinates are calculated by the following equation. Ecliptic latitude can be regarded as 0.

$$
\begin{array}{lllll}
\lambda_s = 279^{\circ}.0358 + 360^{\circ}.00769\,T & & & & \\
\quad + (1.9159 - 0.00005\,T) & \sin(356.^{\circ}531 & + & 359^{\circ}991\,T) & \\
\quad + 0.0200 & \sin(353.06 & + & 719.981\,T) & \\
\quad - 0.0048 & \sin(248.64 & + & 19.341\,T) & \\
\quad + 0.0020 & \sin(285.0 & + & 329.64\,T) & \\
\quad + 0.0018 & \sin(334.2 & - & 4452.67\,T) & \\
\quad + 0.0018 & \sin(293.7 & - & 0.20\,T) & \\
\quad + 0.0015 & \sin(242.4 & + & 450.37\,T) & \\
\quad + 0.0013 & \sin(211.1 & + & 225.18\,T) & \\
\quad + 0.0018 & \sin(208.0 & + & 659.29\,T) & \\
\quad + 0.0007 & \sin(53.5 & + & 90.38\,T) & \\
\quad + 0.0007 & \sin(12.1 & - & 30.35\,T) & \\
\quad + 0.0006 & \sin(239.1 & + & 337.18\,T) & \\
\quad + 0.0005 & \sin(10.1 & - & 1.50\,T) & \\
\quad + 0.0005 & \sin(99.1 & - & 22.81\,T) & \\
\quad + 0.0004 & \sin(264.8 & + & 315.56\,T) & \\
\quad + 0.0004 & \sin(233.8 & + & 299.30\,T) & \\
\quad + 0.0004 & \sin(198.1 & + & 720.02\,T) & \\
\quad + 0.0003 & \sin(349.6 & + & 1079.97\,T) & \\
\quad + 0.0003 & \sin(241.2 & - & 44.43\,T) & (4.3\text{-}1)
\end{array}
$$

$$r_s = 10^q, \text{ (AU)} \qquad (4.3\text{-}2)$$

$$
\begin{array}{lllll}
q = (-0.007261 + 0.0000002\,T) & \cos(356^{\circ}.53 & + & 359.991\,T) + 0.000030 & \\
\quad - 0.000091 & \cos(353.1 & + & 719.98\,T) & \\
\quad + 0.000013 & \cos(205.8 & + & 4452.67\,T) & \\
\quad + 0.000013 & \cos(62 & + & 450.4\,T) & \\
\quad + 0.000013 & \cos(105 & + & 329.6\,T) & (4.3\text{-}3)
\end{array}
$$

Here, time argument T is time that has passed after year 1975 1 mo. 0 day. 0 hour ET, indicated in 365.25 day increments by calendar time, UTC can be calculated as follows.

$$W = [\text{year} - 1900] / 4$$

$$F = W - [W]$$

with this, ([ ] is Gauss symbol)

Y = [1461 W]
X = [(month + 7) / 10]
R = [1 - F]
S = [0.44 (month + 4.4)]

Thus, number of days that have passed by midnight of the observation day will be calculated as follows:

Z = Y + 31 x month + day + (X - 1)R - XS - 27424 (4.3-5)

Also fractions of the day will be:

J = /24 + /1440 + /86400 (4.3-6)

Therefore, passing time t by world time shall be led as follows:

t = (Z + J) / 365.25 (4.3-7)

By converting this number to calendar time using the following equation, time argument T will be led as follows:

$T = t + (0.0317\ t + 1.43) \times 10^{-6}$ (4.3-8)

Since geocentric distance r_s is AU (astronomical unit), by multiplying by $A = .49597870 \times 10^{11}$m , it should be converted into regular measuring unit .
Since calculation load of the above equation is excessive, calculation shall be simplified. Time range of 1 path allow approximation of sun celestial longitude of the sun as follows: Assuming time argument at a certain time t_0 is T_0 and celestial longitude of the sun then is $\lambda_s{'}_0$, celestial longitude of the sun $\lambda_s{'}$ at arbitrary close time t shall be:

$$\lambda_s{'} = \lambda_s{'}_0 + 360^\circ.00769 \Delta T \quad (4.3\text{-}9)$$

here, $\Delta T = (t - t_0) / 86400 / 365.25$

However, time t is supposed to have been calculated in seconds. And geocentric distance of sun in a sufficiently small time range can be regarded as invariable. In OCTS processing, time at the first frame of a scene shall be used as standard.

(2) Calculation of solar position at ECR

Solar position at ECI coordinates can be calculated by using inclination of ecliptic ε
Solar position (X_I , Y_I , Z_I) are calculated as follows:

$$\begin{pmatrix} X_I \\ Y_I \\ Z_I \end{pmatrix} = r_s \begin{pmatrix} 1 & 0 & 0 \\ 0 & \cos\varepsilon & -\sin\varepsilon \\ 0 & \sin\varepsilon & \cos\varepsilon \end{pmatrix} \begin{pmatrix} \cos\lambda'_s \\ \sin\lambda'_s \\ 0 \end{pmatrix} = \begin{pmatrix} r_s \cos\lambda'_s \\ r_s \sin\lambda'_s \cos\varepsilon \\ r_s \sin\lambda'_s \sin\varepsilon \end{pmatrix} \quad (4.3\text{-}10)$$

In this equation, inclination of ecliptic ε is calculated with time argument T.

$$\varepsilon = 23^\circ.44253 - 0^\circ.00013T + 0^\circ.00256\cos(249^\circ - 19^\circ.3T) + 0^\circ00015\cos(198^\circ + 720^\circ T) \quad (4.3\text{-}11)$$

Refer to 4.2.1 for conversion from ECI to ECR.

4.4 Determination of a Scene

OCTS scene is determined within the range of the same tilting angle. For GAC, entire observation area during daylight with the same tilting angle is determined as one scene. For RTC, one scene is entire receiving range in principle, two scenes may be divided, one for before and one for after when tilting angle is changed. For this purpose, telemetry is extracted to determine frames (OCTS' major frames) both for starting and ending of tilting angle change.

On the other hand, the frame time is determined simultaneously with the detection of tilting angle, and the time for all scan line (OCTS major frame) in one scene is calculated. See Section 4.1 "Time Correction" for the method of time determination.

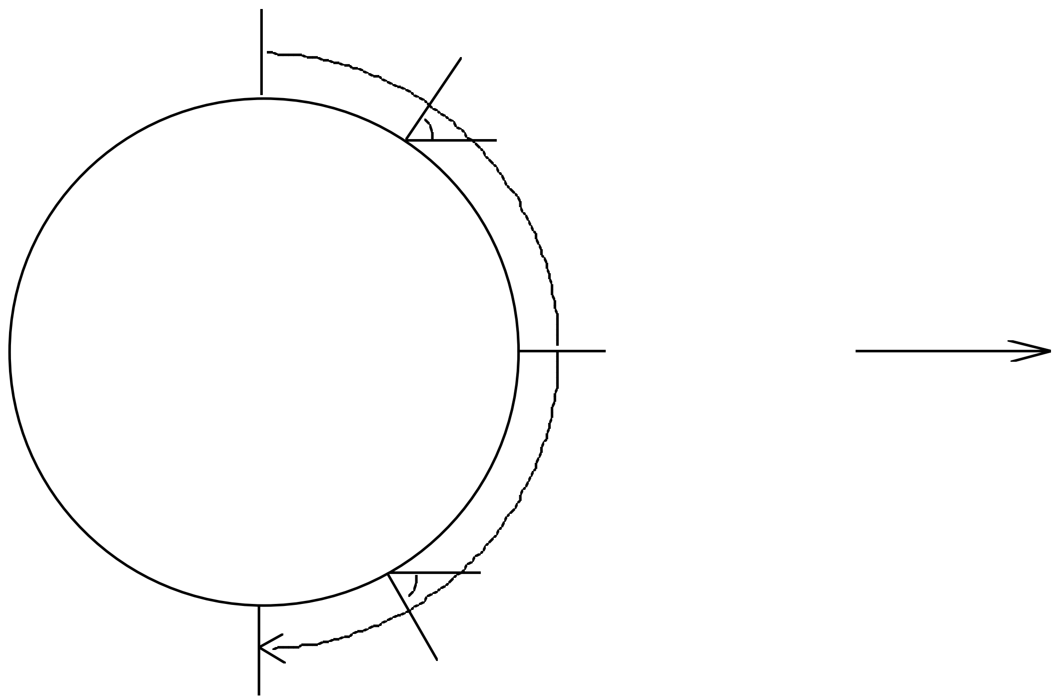

Fig.4.4-1 Tilt Segment

4.4.1 Determination Of Daylight Area

GAC processes only data during daytime. Shadow portion is not processed if observation path includes both daylight and shadow portions. Therefore, satellite position is calculated frame by frame from the very beginning of raw image of the first segment, and the sun elevation angle is calculated, then the first frame whose sun elevation angle exceeds a certain degree is determined as the Input initiation frame. And one frame before sun elevation angle goes below a certain degree is determined as the Input ending frame.

Sun elevation angle at the imaging point (satellite nadir point is represented as the point to calculate the sun elevation angle) is calculated by satellite position and sun directional vector at the time of the frame.

(1) Calculation of satellite and sun position

Satellite and the sun position in ECR is calculated from frame time by each OCTS major frame. See Section 4.2 and 4.3 for calculation methods.

(2) Calculation of the sun elevation angle

Satellite nadir point is represented for the point to calculate the sun elevation angle, because tilting angle is operated as zero degree for the initiation and ending time for one observation path.

When satellite position in ECR coordinates is expressed as (X,Y,Z), latitude and longitude of nadir point (ϕ, λ) is calculated as follows;

$$\phi = \arctan\left(\left(1-e^2\right)\tan\varphi\right)$$

$$\tan\varphi = \frac{Z}{\sqrt{X^2+Y^2}} \qquad \cdots\left(X^2+Y^2 \neq 0\right)$$

$$\lambda = \begin{cases} \frac{\pi}{2} - \arctan\left(\frac{X}{Y}\right) & \cdots(Y>0) \\ -\frac{\pi}{2} - \arctan\left(\frac{X}{Y}\right) & \cdots(Y<0) \\ 0 & \cdots(X \geq 0, Y=0) \\ \pi & \cdots(X<0, Y=0) \end{cases} \qquad (4.4\text{-}1)$$

where, e is eccentricity of earth ellipsoid.

Direction Vector **n** expresses vertical upward at nadir point is,

$$\mathrm{n} = \begin{pmatrix} l \\ m \\ n \end{pmatrix} = \begin{pmatrix} \cos\phi\cos\lambda \\ \cos\phi\sin\lambda \\ \sin\phi \end{pmatrix} \qquad (4.4\text{-}2)$$

If position vector of the sun in ECR coordinate system is written as , s= (X_s, Y_s, Z_s), the sun elevation angle η is calculated as follows;

$$\cos\left(\frac{\pi}{2}-\eta\right)=\frac{\mathrm{s}\cdot\mathrm{n}}{|\mathrm{s}||\mathrm{n}|}=\frac{X_s l+Y_s m+Z_s n}{\sqrt{\left(X_s{}^2+Y_s^2+Z_s{}^2\right)}} \qquad (4.4\text{-}3)$$

Therefore, conditions for daylight will be as follows:

$$\sin\eta=\frac{X_s l+Y_s m+Z_s n}{\sqrt{X_s{}^2+Y_s{}^2+Z_s{}^2}}\geq\sin\eta_0 \qquad (4.4\text{-}4)$$

Here, η_0 is input start elevation angle led by database.

when input the size of the earth is neglected as it is considerably small compared to the distance to the sun.

4.4.2 Determination Of Tilt Segment

Change of tilting angle in the orbit is started when the command for OCTS is accepted and is ended when tilting angle reaches target tilting angle. Therefore, one frame before the frame whose tilting angle is switched in DSP status of telemetry is the scene ending frame, and frame which stabilizes at fixed value for tilting angle telemetry value is the starting frame of the next scene. However, if tilt angle of DSP status is changed in consideration of bit error, it decides that tilt angle has actually been changed when certain number of frames continue, and the results of this frame number before the change is regarded as the ending frame of the previous scene. For change of tilt angle, when the difference between tilt angle telemetry value and the one before goes below a certain value, the change is considered complete and the next scene starts from the frame measured last. Since tilt angle telemetry is sent in four frame increments, tilt angle is determined by a set of four frames by identifying the beginning of the word. In cases where length of tilt segment goes below a specified frame length, it will not be generated as a scene (not to be processed). See 4.5 for engineering value conversion of tilt angle telemetry.

4.5 Telemetry processing

4.5.1 Extraction of telemetry status

The following status information is extracted from telemetry data:

• Observation mode
• DSP/ A/B
• Tilt angle
• Visible and near infrared gain (Ocean /Land, High/Normal : each band)
• Thermal infrared gain (gain 1 / gain 2 /gain 3 : each band)
•Scan driving control segment primary system/ secondary system (Scan Drive Electronics Primary system / secondary system)

In cases where the number n of the same status is not continued (input from database), or unauthorized value, data valued should be judged the status before and after due to the first inspection error. Regarding Scan driving control segment, since there is no status information in OCTS telemetry, larger of the telemetry output of the two items below should be regarded as ON. (If the results from two items, it should be regarded as the first inspection error.

Primary System:	Scan driving control segment A	Tilt control error voltage (word 53)
	Scan driving control segment B	Tilt motor voltage (word 55)
Secondary System:	Scan driving control segment B	Tilt control error voltage (word 54)
	Scan driving control segment B	Tilt motor voltage (word 56)

4.5.2 Engineering Transformation Of Telemetry

Telemetry of the following items should be converted to engineering values:

• Tilt angle
• Temperature of optics assembly cover (Visible and near infrared detector temperature 1•2,Visible and near infrared preamplifier segment temperature 1•2, instead of IR preamplifier segment 1-4)
• IR detector temperature (1/2) (fine)
• SRU Structure temperature 2 (instead of analog multiplex segment temperature)
• SRU Structure temperature 1 (instead of A/D conversion segment temperature)
• Calibration segment Reference black body temperature 1
• Calibration segment Reference black body temperature 2
• Calibration segment Reference black body temperature 3
• Calibration segment Reference black body temperature 4
• Calibration segment Reference black body temperature 5
• Analog multiplex segment power voltage
• Thermal control circuit segment Constant current calibration signal

(1) Conversion of engineering value of tilt angle

Tilt angle telemetry data is 18 bits data and sent in 4 frame increments. 1 frame / 6 bit is sent from the upper bit. Bit assign of tilt angle telemetry is shown in Fig. 4.5-1.

Tilt angle telemetry value I in 18 bits is converted into angle by the following equation:

$$\theta'' = \frac{360}{2^{18}} I \qquad \text{(degree)}$$

Resolver calibration is performed on the above tilt angle values using tilt angle calibration table.

Bit	9	8	7	6	5	4	3	2	1	0
word	Unused		Word ID		Tilt Angle					
1	1	1	0	0	b17	b16	b15	b14	b13	b12
2	1	1	0	1	b11	b10	b9	b8	b7	b6
3	1	1	1	0	b5	b4	b3	b2	b1	b0
4	1	1	1	1	Reserved					

Fig. 4.5-1 Tilt Angle Telemetry

(2) Transformation of engineering values of voltage telemetry

Analog multiplexer power voltage telemetry count values is transformed to engineering values using the following equation:

$V[V] = C \bullet N$

where C: coefficient to convert digital values into voltage (5/1023)

(3) Transformation of engineering values of temperature telemetry

a) Thermistor (THR52CNA501F)

Temperature of optics assembly cover, calibration segment reference black body temperature 1, SRU Structure temperature 1•2 can be converted into engineering values using the following equation:

1. Calculation of constant current values

Current values I_0 can be led by the following equation:

$$I_0[A] = C \bullet N_0 / R_0 \qquad (4.5\text{-}1)$$

Where, C: Coefficient to convert digital values to voltage (5/1023)

N_0: Digital values of telemetry (constant current calibration at thermal control circuit) constant current for reference resister

R_0: Resister values of reference resister (SOOH correction table 21)

2. Calculation of resister values of temperature sensor
Register value R of both ends of the thermister of each temperature sensor is calculated by constant current values using the following equation;

R [•] = C • N / I_0= N /N_0 • R_0 (4.5-2)

where, N : Digital value of each temperature telemetry

3. Calculation of temperature
Register value of temperature sensor will be converted to temperature T using the following equation:

$$T[^\circ C] = \frac{1}{a_0 + a_1 \cdot \log_e X' + a_2 \cdot (\log_e X')^2} - 273.15 \qquad (4.5\text{-}3)$$

Where, a_0, a_1, a_2 are constant (unique to each segment : calibration table 27), X' is:

X' = R / 500

b) Thermister (THR51CNA102F)
Calibration segment reference black body temperature 2 - 5 are transformed to temperature T using the following equation:

$$T[^\circ C] = \frac{1}{a_0 + a_1 \cdot \log_e X' + a_2 \cdot (\log_e X')^2} - 273.15 \qquad (4.5\text{-}4)$$

Where, a_0, a_1, a_2 are constant (unique to each segment : calibration table 27), X ' is:

X' = R / 1000

R is the same as a)

c) Other temperature
IR detector temperature (fine) is transformed to temperature T by the following equation:

$$T[^\circ C] = a_0 + a_1 \cdot V + a_2 V^2 + a_3 V^3 + a_4 V^4 - 273.15 \qquad (4.5\text{-}5)$$

Where V = C • N

C: Coefficient to convert digital values to voltage (5/1023)

N: Digital values of each temperature telemetry

However, $a_0 \sim a_4$ is constant values (unique to each segment : calibration table 14)

4.5.3 The Preliminary Inspection Of Telemetry Data

Telemetry data is inspected for upper limits and lower limits and variation. That is, if one of the following is applied, the preliminary inspection will be regarded as error:

$$\begin{cases} T_i < T_{\min} \\ T_i > T_{\max} \\ |T_i - T_{i-1}| > T_v \end{cases}$$

Where T_i : First telemetry engineering value

$T_{\min}$: Lower limits
$T_{\max}$: Upper limits
T_v : Limit value of variation

Inspection will be performed within scene extent. For inspection of tile angles, upper limits and lower limits vary by each tilt. Inspection during tilt change should not be performed. (not in the scene extent)

4.6 Processing of attitude data

As for attitude data, attitude error angles and angular velocities are telemetered. However, only error angles are used. Attitude angles are interpolated to every scan time. Attitude angles are measured every second and delivered with satellite time. Measurement time of attitude angles is before 968.8 msec ±125 msec to satellite time. But component of ±125 msec is regarded as stable for a scene, and it cannot be detected on orbit, so it is ignored.

4.6.1 Restoration of attitude data

Attitude data is calibrated on board. Altitude error of 1LSB is 10^{-3} . However, since attitude angle is measured one second period and OCTS frame period is 0.905 sec. , these are not synchronized. Therefore, there are cases where the same attitude data and satellite time are stored consecutively in telemetry in OCTS. When this occurs, rearrange attitude data within a scene in original one second intervals.

4.6.2 Preliminary inspection of attitude data

Preliminary inspection is performed to attitude data restored in one second intervals. Criteria for preliminary inspection are, as the same for the other telemetry, upper limits, lower limits and variation.

4.6.3 Interpolation of attitude data

Attitude angle by each scan line is calculated by interpolation to time of OCTS scan line. The third degree Lagrange interpolation method is applied for this. Section 4.2 " Processing of Orbit Data " is referenced to this Lagrange interpolation.

In cases where data frame is damaged or failed the preliminary inspection, liner interpolation should be performed for missing data value. If data between attitude angle A_i and A_j is failed, the data in between A_k is determined as follows.

$$A_k = A_i + \frac{A_j - A_i}{j - i}(k - i) \qquad (i < k < j) \qquad (4.6\text{-}1)$$

However, if the beginning or the last of data is erroneous, the erroneous data should be replaced with the correct beginning or the correct last data.